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1984 Annual Report of the Kennedy Space Center

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FOREWORD

As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to Space Station and other future programs. In connection with the increasing emphasis on research and technology, the Directorate of Engineering Development encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1984 Annual Report. The report contains brief descriptions of research and technology projects in major areas of Kennedy Space Center's disciplinary expertise.

For further technical information about the projects, contact Albert E. Jorolan, Engineering Development, Research and Technology Manager, DL-RT, (305) 867-4856. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.



Richard G. Smith
Director

AVAILABILITY INFORMATION

For additional information on any summary, contact the individual identified with the highlight. Commercial telephone users may dial the listed extension preceded by area code 305. Telephone users with access to the Federal Telecommunications System may dial the extension preceded by 823.

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Cyrogenic Engineering

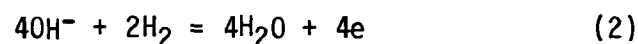
High-Purity Oxygen Production

Reversing the bias on a fuel cell can produce high-purity oxygen, usable as a feed gas. The fuel cells on the Shuttle require oxygen of high purity--at least 99.989% pure. The standard technique for its preparation has been distillation. A fuel cell itself, however, can be used to produce its own high-purity feed by operating as a concentration cell.

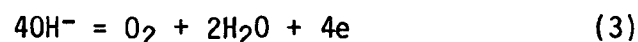
In normal operation, the cathode of the alkaline fuel cell reduces the oxygen feed, producing hydroxyl ions:



These hydroxyl ions migrate to the anode where they react with feed hydrogen to produce water and electrical energy:



If, instead of feeding hydrogen to the anode, an electrical voltage is applied to drive the anode potential up sufficiently to reverse the cathode reaction:



highly pure oxygen is evolved. In this process, impure oxygen is fed to the cathode, or perhaps even air that has been scrubbed of carbon dioxide is used. A more efficient feed would be propellant-grade oxygen, however. In this way, fuel-cell-grade oxygen could be produced at the launch site at the expense of only electrical energy and propellant oxygen.

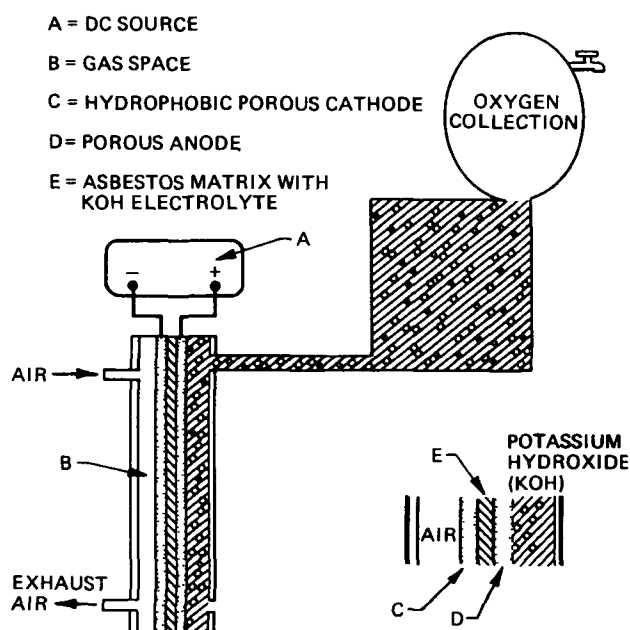
Laboratory-scale experiments have been conducted to determine both the product purity and the cell performance. The latter is a measure of the required cell potential for any given rate of oxygen production. This information is necessary to derive cost figures both for the cells and their operation.

The results have been highly encouraging. Purity of 99.996% has been obtained in long-term tests with feeds of either air or propellant oxygen. The tests also confirm that current density of the same order as that reached in flight can be reached in the 'driven' mode. The performances of the individual electrodes, as determined with the aid of a reference electrode, are equivalent to or exceed the performance of those now in use. Current densities of up to 500 mA/cm² are reached with overpotentials under 1.2 V and a flux of 0.3 lb of oxygen/ft²/h.

Complete information is now available to design a full-scale system. The economics appear attractive. The operating costs are quite low, but total cost is very dependent on the purchase cost for the full-scale fuel cells.

K. Buehler, 867-3332

DD-MED-43



Schematic diagrams of the oxygen - oxygen cell for preparation of pure oxygen.

Natural Condensation Flow and Heat Transfer of Oxygen in a Helically Coiled Heat Exchanger

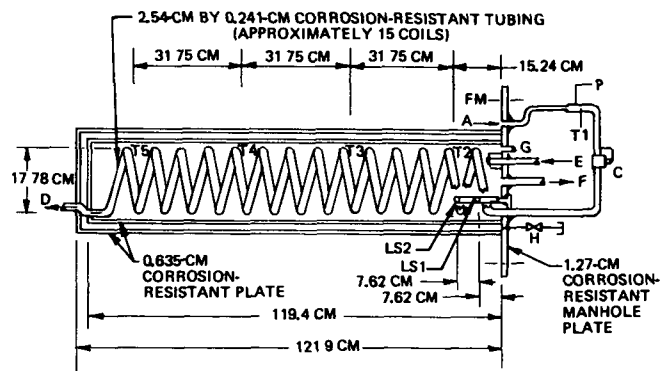
During each Shuttle flight, the Orbiter's fuel cells use hydrogen and high-purity oxygen to generate electrical power and drinking water. Between flights, the high-purity oxygen is stored in liquid form in a ground storage Dewar. If the Dewar is vented, the liquid oxygen will become methane-rich and, thus, not suitable for feeding the fuel cells. To prevent venting, a helically coiled heat exchanger has been designed, fabricated, and installed in the Dewar to condense the boil-off gas. The heat exchanger uses liquid nitrogen as cooling fluid. The heat-exchanger/Dewar configuration has been tested extensively.

To provide test data on condensation flow and heat transfer of oxygen in a helical coil, a flowmeter and pressure and temperature transducers were installed in the oxygen flow loop. Additionally, thermocouples were soldered to the helical coil. From the measurements by these devices, natural condensation flow and heat transfer of oxygen in a helical coil and boiling heat transfer of liquid nitrogen from a helical coil have been calculated.

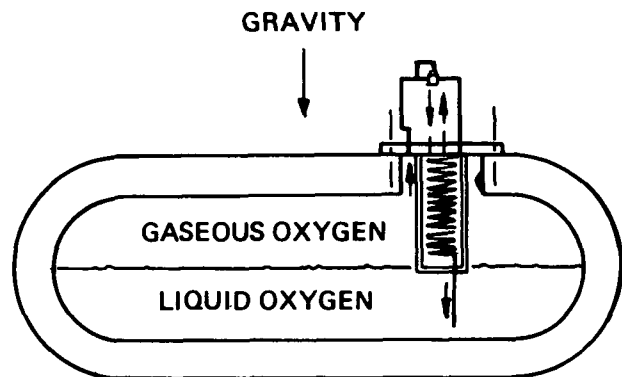
The ranges of wall-to-fluid temperature difference (T) covered by the condensation and boiling heat transfer data are 6°F to 24°F and 8°F to 18°F , respectively. The values of condensation heat transfer coefficient at $T = 6^{\circ}\text{F}$ and 24°F are, respectively, 400 and 80 $\text{Btu}/(\text{h ft}^2 ^{\circ}\text{F})$; and the values of boiling heat transfer coefficient at $T = 8^{\circ}\text{F}$ and 18°F are, respectively, 280 and 120 $\text{Btu}/(\text{h ft}^2 ^{\circ}\text{F})$. A report describing the heat exchanger, the test procedures, and the test data is available upon request.

F.N. Lin, 867-4156

DD-MED



Heat exchanger schematic.



Zero-Loss liquid-oxygen Dewar.

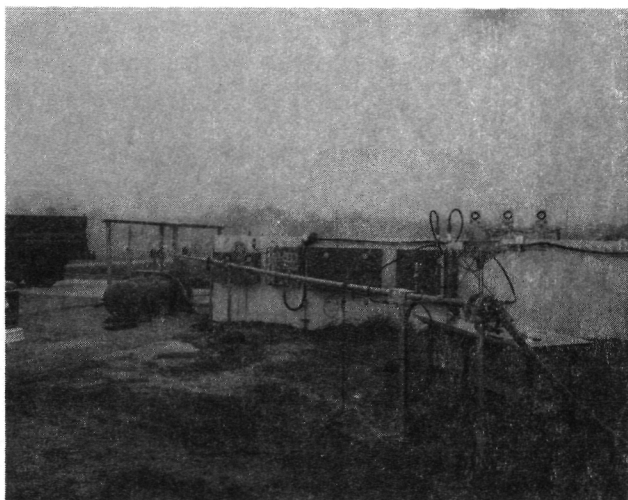
The Effect of Sense Line Length on Waterhammer Pressure in a Cryogenic Flow

All existing pressure transducers in KSC's liquid oxygen servicing system have long sense lines--30 ft for the Orbiter inlet transducer, 37 ft for the skid outlet transducer, and 29 ft for the skid inlet transducer. These transducers have measured a waterhammer pressure effect that is much higher than analytically predicted values. All available data indicate that this discrepancy appears to be due to the long sense lines. To examine the effect of sense-line length on the waterhammer pressure, a series of tests was conducted at KSC's Prototype Laboratory.

In all tests, liquid nitrogen was used as the test fluid. The test setup can generate a waterhammer pressure as high as 1,000 lb/in². Sense-line lengths ranging from 3 in to 40 ft were tested. Preliminary data analysis indicates that, for sense lines between 15 in and 40 ft, the length can amplify the waterhammer pressure as much as 40%. However, it has no effect on steady-state pressure or low-response pressure changes. Additional testing and data analyses are required before the phenomenon can be explained.

F.N. Lin, 867-4156

DD-MED



Test setup for determining effects of sense-line length on waterhammer pressure.

Magnetic Refrigeration of Liquid Hydrogen Boiloff

Under a KSC contract initially funded from the KSC Center Director's 1982 discretionary fund, Los Alamos National Laboratories of Los Alamos, New Mexico, has been in the process of developing the technology of refrigeration by magnetism. The purpose of this project is to provide a more thermodynamically efficient system than those using compressors and expanders. The ultimate goal of the magnetic refrigerator is to chill hydrogen gas from ambient temperature to

liquid temperature. The principle of the system is to use the magnetocaloric effect of heating and cooling of a magnetic material upon application and removal of a magnetic field at the curie temperature of the magnetic material to which the gas is exposed. The application and removal of the magnetic field is more efficient than the classical method of applying and removing pressure from a gas using a compressor and expander.

During initial development of the KSC refrigerant system, analyses of the refrigeration requirements and the refrigerator options were made. Measurements were also made of the magnetic properties of potential gadolinium compounds to be used in the refrigerator. Properties measured were density, magnetic susceptibility, heat capacity, and adiabatic temperature change.

Development of the 10-liter-per-hour hydrogen boiloff-gas reliquifier prototype model is underway. Since the last annual Research and Technology Report, a number of things have been accomplished. The superconducting magnet was designed and ordered from Cryomagnetics of Oak Ridge, Tennessee, with an expected delivery date of January 1985. The design of the liquid helium Dewar is complete. The design of the drive mechanism is underway. Design drawings on the high-efficiency regenerator bed and the magnetic material bed are complete.

Determination of ways to solve seal problems on the drive mechanism and details on how the magnetic material bed is to be manufactured are in work. Plans are to have a working prototype reliquifier by the issue of the 1985 Research and Technology Report.

F.S. Howard, 867-3202

DD-MED-4

Polygeneration

Polygeneration is an innovative approach to reducing cost for energy-intensive propellants and consumables used in the

Space Shuttle Program at KSC. For about 3 years, the KSC Engineering Development Directorate has had a project team investigating the economic and technical feasibility of the Polygeneration approach. "Polygeneration" describes a process that will produce liquid hydrogen (LH₂), gaseous and liquid nitrogen (GN₂ and LN₂), liquid oxygen (LO₂), and electricity from an integrated, coal-gasification, combined-cycle (IGCC) power plant. A key element of the Polygeneration approach is the production of high-value products using the least costly feedstock--high-sulfur coal--with the maximum integration and utilization of byproducts. The result is potential savings of over 40%, or approximately \$850 million over the life of the project, for operations cost at KSC. Another side benefit of the project is the commercial demonstration of coal-utilization technology with proven potential to reduce acid-rain-causing pollutants by 1 to 2 orders of magnitude over existing state-of-the-art technology in use by the power industry.

Presently, the design feasibility stage of the project is completed and is being reviewed by NASA management prior to a decision to proceed with implementation. Because of the significant savings achievable with such a plant at KSC, the potential is very good that the project, in one form or another, will proceed.

The coal-gasification and gas-cleanup system gasifies the input coal and cleans up the output gas to produce a clean, medium-Btu gas composed primarily of carbon monoxide (CO) and hydrogen (H₂). It has a Btu content of approximately 300 Btu's per standard ft³ as compared to natural gas, which has about 1,000 Btu's per standard ft³. This medium-Btu gas can be used as a hydrocarbon feedstock for producing pure H₂ and can also be combusted, similar to natural gas, in a combustion turbine for producing electrical power. In addition, depending on the particular gasification process used, the gas stream exits the gasifier at a temperature of about 2,500 °F. It is possible to recover the ther-

mal energy of this gas stream by means of a waste-heat boiler system. This system can then provide thermal energy for facility use or for steam to an IGCC power plant.

Coal-gasification processes use either air, oxygen (O₂), or O₂-enriched air. Using O₂ in the gasification process has several advantages. It increases the Btu content of the output gas stream, since the natural GN₂ content of air is not present to dilute the output gas. In addition, carrying the GN₂ would only serve to increase the quantity of output gas and would require downstream processing units to be oversized to handle the large gas stream. Additional processes would also have to be added to remove the GN₂ downstream in order to produce H₂ of the purity required. For these reasons, O₂ is provided by means of a cryogenic air-separation plant. In addition to providing O₂ for the coal-gasification process, large quantities of pure GN₂ are available as a byproduct from the air-separation plant, and this can be used at KSC to meet existing requirements for GN₂ purge.

The medium-Btu gas stream coming from the gasifier can now be used both as a feedstock for making LH₂ and as a gas turbine fuel. Its composition will be primarily CO and H₂ with some carbon dioxide (CO₂). This composite gas is an excellent feedstock for making H₂ by means of the water (H₂O) shift reaction. The H₂O shift reaction in simplified form is as follows:



(Another concept would remove GH₂ directly from the gas stream by use of membrane-separation technology without the need for the shift reactor.)

The CO₂ can be separated and the H₂ purified by a number of commercial processes that leave a pure H₂ stream, which is fed to a standard H₂ liquefaction plant, and then pipelined or transported to the LH₂ storage tanks at

Launch Complex 39, Pads A and B, for use by the Space Shuttle.

The medium-Btu gas, as mentioned earlier, also can be used directly as a gas turbine fuel. Use of medium-Btu gas in gas turbines is not common in the United States, but there is growing commercial experience. Existing off-the-shelf United-States-designed gas turbines can use medium-Btu gas with relatively minor combustor modifications to accommodate higher mass flows and combustion temperatures. The high-temperature gas turbine exhaust can be used in a heat-recovery steam generator along with the steam generated by the gasifier waste-heat system to produce superheated steam. The superheated steam can be expanded through a steam turbine for producing electrical power. This arrangement is referred to as an IGCC power plant. Thermal energy from the steam cycle may also be used for facility

heating and air-conditioning. The electricity produced in the IGCC plant can serve not only the large power needs of the air-separation plant and LH₂ plant, but also part or all of the KSC facilities' power requirements.

The interrelated requirements of coal gasification, LH₂ production, and electrical and thermal energy production and KSC's unique needs for these products naturally lead to an integrated Poly-generation plant as described. The synergism inherent in this approach to LH₂ production, combined with IGCC power production and the lower cost of coal as a primary feedstock, provides a unique opportunity for reduction in the cost factors of producing LH₂. This offers the potential for significant cost savings for KSC and the Space Shuttle Program.

G.P. Gutkowski, 867-2196

DF-PEO

Hypergolic Engineering

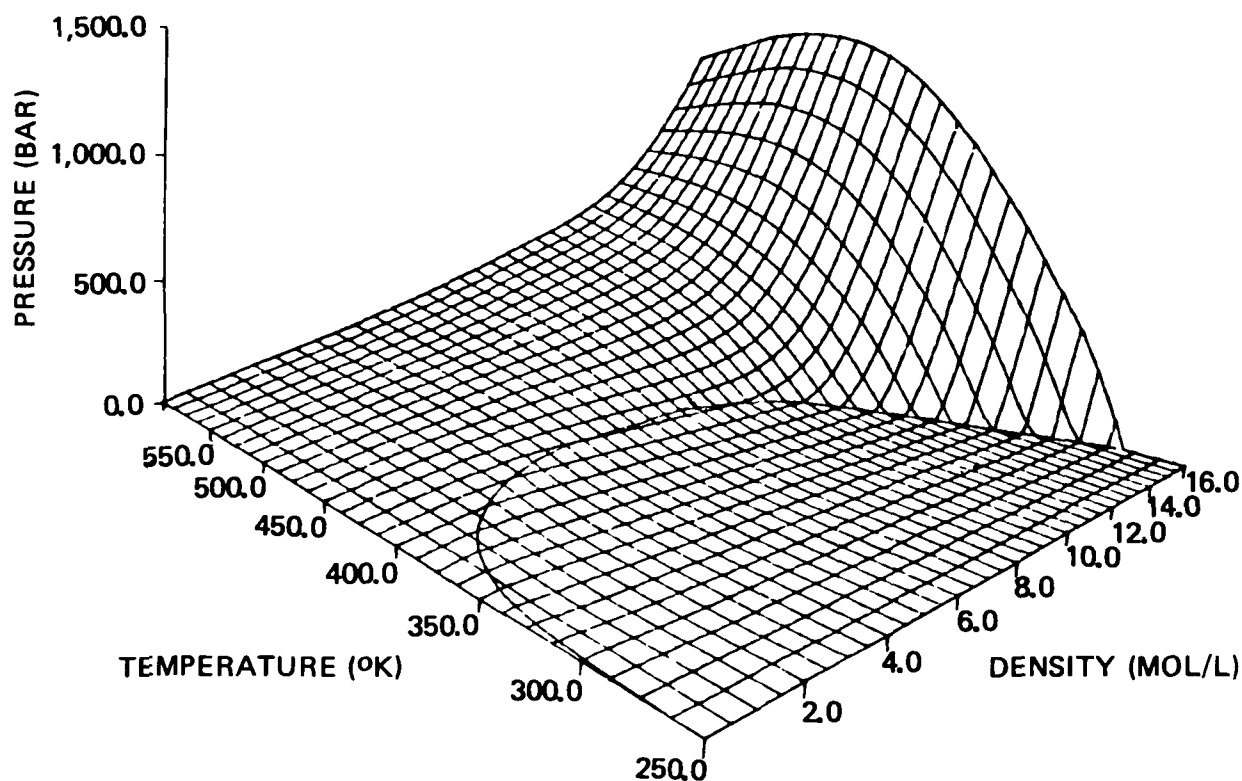
Nitrogen Tetroxide (N₂O₄) Thermophysical Properties Tables

During Space Shuttle servicing with N₂O₄ at KSC, there were times when unexpected quantities of nitrogen dioxide vapor were generated by N₂O₄ boiloff. This led to the rapid depletion of scrubbing liquor in oxidizer hypergolic vapor scrubbers. The prime reason for N₂O₄ boiloff is that its boiling point is 70°F at atmospheric pressure. Because of limited data on the thermodynamic and transport properties of N₂O₄, it was difficult to make calculations concerning this and similar N₂O₄ problems. Therefore, it was desirable to develop tabular data similar to that developed for cryogenic media in NASA SP-3089,

"Hydrogen Technical Survey - Thermodynamic Properties." The National Bureau of Standards has developed these N₂O₄ tabular data.

In the development of the N₂O₄ thermophysical properties tables, the problem of developing an equation of state for this fluid was more difficult than originally expected because of the chemical reaction, changing N₂O₄ to nitrogen dioxide and back to N₂O₄, that takes place as the state conditions are changed. It was necessary to treat the fluid as a mixture rather than as a pure fluid.

The problem has been solved, and the pressure-volume-temperature equation of state has been determined by the National Bureau of Standards. The equa-



Plot of 32-parameter, modified, Benedict-Webb-Rubin equation.

tion used to model the pressure-volume-temperature surface is a 32-parameter, modified, Benedict-Webb-Rubin equation.

The thermophysical properties tables will serve as a valuable tool in the design and operation of N_2O_4 systems. The goal for completion of the thermophysical properties tables is December 1984.

F.S. Howard, 867-3202

DD-MED-4

Hypergolic Fuel Absorber and Neutralizer

In the handling and distribution of hydrazine fuels, unwanted liquid spills occur during repair, transfer, and venting. There is a need for a material that can be applied quickly to any surface (steel, plastic, concrete) and that will dispose of the hydrazine in a manner so that it will reduce evaporation of the fluid; react and neutralize in a controlled, nonviolent manner (no fire, explosion, high heat, or corrosive reaction); and reduce toxicity to a level where disposal can be safely accomplished without special protective mea-

sures. A feasibility study was performed by Auburn University to investigate novel means to accomplish this goal.

The study addressed contacting schemes and specific reagents believed to be favorable for the neutralization of hydrazine spills. The reactive species considered are transition metal oxides, sodium and calcium hypochlorites, iridium (IV) halogeno complexes, polymeric materials, and silica, silica-alumina clays or other types of tailored adsorbents. The contacting schemes involved are dry pellets, wet pellets, specialized adsorbents, and solid reactive materials.

The goal of the report was to further quantify and rank the suitabilities of suggested neutralization mechanisms (viz., mechanism = reactant + contacting scheme) in order to ascertain their feasibility and potential for further evaluation and development efforts. A follow-on effort is being accomplished by Auburn to perform laboratory reaction phenomena and prototype materials testing.

R.A. Gerron, 867-4493

SF-ENG

Hazardous Warning Instrumentation

Fiber-Optic Liquid-Leak Detector Development

The many fluid systems required to perform ground support, checkout, and launch of the Space Shuttle are known to leak upon occasion. Many of the systems are in remote, hazardous, or inaccessible locations. In addition, many of the spacecraft fluid systems are covered in a layer of thermal insulation, making leak detection a difficult and time-consuming task. These problems have led to an effort to develop a technique to detect fluid leaks remotely in these types of systems. In the case of spacecraft systems where the leak detection system will have to fly, compact and lightweight sensors are required.

KSC has begun an effort to develop fiber-optic liquid-leak sensors and a readout system. This effort has resulted in a contract awarded to Opto-Electronics, Incorporated, of Oakville, Ontario. The contract will result in a minimum of four working prototype sensors and a breadboard readout or interrogation system.

To date, the contract has resulted in three basic sensors: U-shaped liquid sensor, tapered-fiber liquid sensor, and tilted-fiber-reflector type liquid sensor. Both the U-shaped and the tapered-fiber sensors operate by allowing light to escape from the fiber in the presence of a fluid in the correct index of refraction range. These types of sensors can be optimized to operate with various fluids. The tilted-fiber-reflector sensor operates by allowing better transmission to occur when in the presence of the proper fluid.

Math models of the sensors have been developed, allowing the optimization of construction parameters during the design of the prototype sensors. The pro-

totype sensors are being designed to sense water and hydraulic fluid. The development of sensors that operate with other fluids will be the goal of follow-on work. The sensors are very compact and may be mounted in several configurations, depending upon the application.

In a typical application, the sensors are installed at potential leak sites, joints, couplings, and fittings, and are read or monitored using an optical time-domain reflectometer technique. This allows multiple sensors to be interrogated using one sense fiber. Calculations indicate that 50 to 100 sensors may be connected to a single sense fiber. This technique monitors reflections, or their absence, and uses time-of-travel information to determine the distance to the activated sensor, pinpointing the leak instantly.

This type of liquid-leak detection system can provide rapid detection and repair of leaks, minimize human exposure to toxic or dangerous fluids, and speed system checkout and integrity verification. The U-shaped sensor has the capability to react to fluids in a very small index of refraction range and may be useful in process control applications.

The effort to develop the sensors, the mechanical interface between the sensor and the fluid system, and the interrogation and readout system is scheduled to continue.

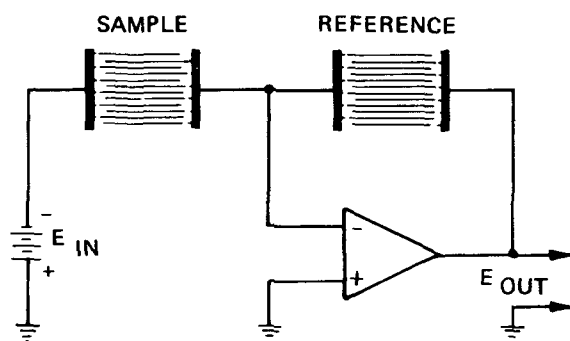
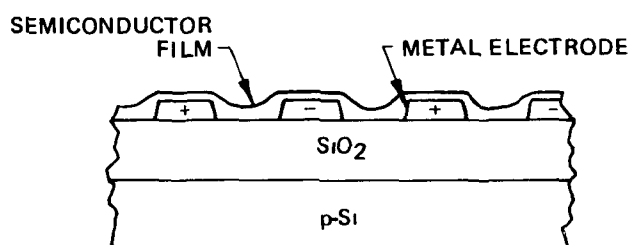
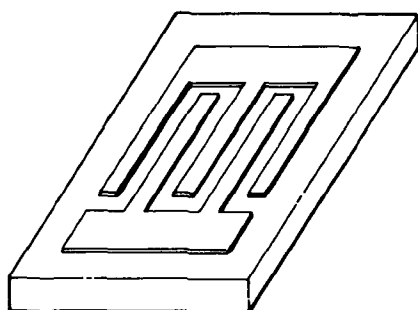
M.E. Padgett, 867-3367

DL-NED-12A

Pattern Recognition Methods for Toxic Vapor Detection Using Microsensors

The objective of this project is to develop a microsensor array capable of measuring hydrazine at the part-per-

billion (ppb) level. Personnel safety requires hydrazine vapor detection at ppb levels. The commercially available instruments cannot reliably detect hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine at the National Institute of Occupational Safety and Health's recommended values of 30, 40, and 60 ppb.



$$E_{OUT} = (E_{IN}) \times \frac{R_{REFERENCE}}{R_{SAMPLE}}$$

Chemiresistor system.

Major advances have been made in microsensor technology and pattern recognition techniques that could improve hydrazine detection. Naval chemical microsensors (chemiresistors) are being developed for the detection of chemical vapors by the Naval Research Laboratory Chemical Division in Washington, D.C. Chemiresistors change resistance when exposed to different compounds, and the magnitude of the change depends on the interaction of the gas vapor with the coating on the microsensor.

Coatings will be developed to make microsensors that will respond to different chemical classes of compounds in a complex air mixture. An array of these sensors will give unique patterns, or "fingerprints," describing the substances present.

Interpretation of the "fingerprint" produced by an array of sensors will be done using pattern recognition methodology. These methods use modern mathematical techniques of multivariate statistics and numerical analysis to improve the measurement process as well as to extract more chemical information. In order to apply pattern recognition techniques to microsensor-array data, the following four premises are necessary:

1. The compounds and the microsensor response are related.
2. Compounds can be represented adequately as a set of microsensor responses.
3. A relation can be discovered between compound and response by applying pattern recognition methods to a set of tested compound mixtures.
4. The relation can be extrapolated to untested mixtures.

One of the keys to successful data analysis through these techniques is the development of descriptors. Descriptors are a means of encoding chemical infor-

mation in a numerical form. In this study, the descriptors are the chemisorption responses. Each compound can be thought of as a point whose position in space is defined by the values of each descriptor. Similar objects will tend to cluster in a space defined by their descriptors. Pattern recognition is a set of methods for investigating the clusters in space.

The classification of the compounds into the appropriate classes will be achieved by selecting the proper descriptors or microsensor coating to form the individual clusters. Through the use of computers and mathematical and statistical methods, the data of interest will be extracted from a complex background. The goal is to quantitate this information and to make progress toward the design of a "smart" detector.

W.R. Helms, 867-4438

DL-NED-32

Hazardous Gas Detection System (HGDS)

The objective of this project is to develop a prototype detector for gaseous propellants used aboard the Space Shuttle. The prototype will be based on the proven Navy Central Atmosphere Monitoring System (CAMS) hardware. It is not the intent of this portion of the project to produce a complete system to replace the current HGDS, but to prove that the CAMS analyzer will meet and exceed the performance and reliability specifications required of the HGDS.

Prior to launch, various compartments of the Space Shuttle are monitored for hydrogen, oxygen, and helium leaks. The Naval Research Laboratory Chemical Division in Washington, D.C. was asked by NASA to adapt the CAMS for this monitoring task. CAMS is used aboard all nuclear submarines and has a mean time between failure greater than 3,000 hours when operated continuously in a submarine environment. It does not require recalibration during its 20,000 hours of average use between refurbishments.

Approximately 40 CAMS analyzers are being refurbished every year. The expertise to refurbish the unit and spare parts, etc., are being maintained and will continue to be maintained by the Navy far into the future.

The mass spectrometer module of the CAMS has been modified to detect helium and argon in addition to hydrogen, nitrogen, and oxygen. Where possible, the CAMS mechanical and electrical hardware was used. For testing and evaluation, the analyzer will be interfaced to a commercial microcomputer system. The system will be tested to determine detection limits, accuracy, linearity, noise, and long-term performance.

Following successful completion of this phase, a sampling system and computer-based controller will be designed and tested. In addition to maintaining the excellent performance capabilities of the present HGDS, the design approach will emphasize simplicity, ease of operation and repair, high reliability (parts meeting military specifications where applicable), and a high degree of user-friendliness.

W.R. Helms, 867-4438

DL-NED-32

Evaluation of a Process Gas Analyzer as a Backup Subsystem for the Primary Hazardous Gas Detection System (HGDS)

The process gas analyzer evaluated in this series of tests was an MGA-1200, multiple gas analyzer manufactured by Perkin-Elmer. The MGA-1200 was specifically designed for online, simultaneous measurement of up to eight components in a given gas stream with parallel analog output.

The MGA-1200 uses a permanent magnet to deflect charged particles emanating from the ion source. These particles receive different trajectories depending upon their mass-to-charge ratio. Faraday collectors are strategically located in

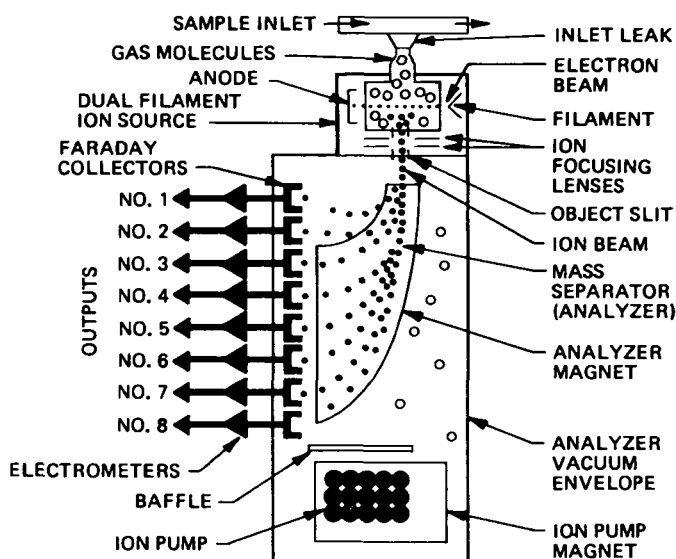
the path of selected particles, and the output from each collector passes through an electronic circuit before being transmitted to either a direct or a ratioed output.

Because this design coincided with NASA's requirements for a backup subsystem for the HGDS and because of the excellent track record of Perkin-Elmer's process gas analyzers in the industrial and military community, the MGA-1200 was purchased and evaluated.

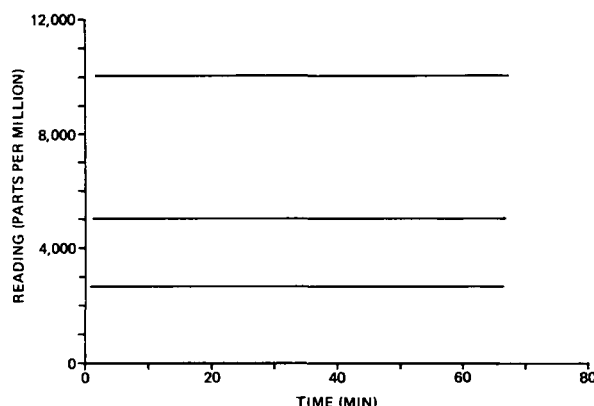
Testing of the MGA-1200 was limited to 2 months, due to Shuttle launch requirements. During the 2 months of laboratory testing, the MGA's performance was exemplary. No maintenance was required, and no calibration drift was observed. Testing was terminated, and the MGA-1200 was installed on Mobile Launcher Platform No. 1 in preparation for Shuttle launch 41C to obtain launch vibration data and to compare its performance with the prime HGDS. To date, three launches have been supported successfully with no vibration problems, and correlation of data between the two instruments has typically been within 10 parts per million. This mass spectrometer has been selected as the basis of a backup HGDS for the Space Shuttle at KSC and at Vandenberg Air Force Base, California, as well as for the Centaur program.

W.R. Helms, 867-4438

DL-NED-32



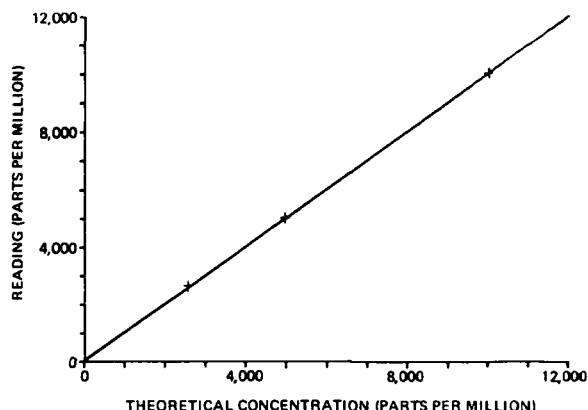
Mass spectrometer operation.



Model MGA-1200 H₂ stability test.

Turbomolecular Pump Testing for Launch Vibration Tolerance

Turbomolecular vacuum pumps, operating at speeds of 20,000 to 60,000 revolutions per minute, vectorially transfer this high-speed rotational momentum to gas molecules, effectively directing their motion from a volume of low concentration into a volume of higher concentration. Consequently, these pumps are capable of achieving vacuums of less than one-billionth of atmospheric pressure. They are used to provide high-vacuum environments required by mass spectrometers, particle accelerators, etc.



Model MGA-1200 H₂ linearity test ($R^2 = 1.000$).

Because of these pumps' high speed, NASA KSC has been reluctant to use turbomolecular vacuum pumps on mass spectrometer systems on the mobile launcher platform due to concern that they would be destroyed by the vibrations encountered during launch of the Space Shuttle. Data on pump performance under such adverse conditions is not available from manufacturers.

Since turbomolecular pumps have some distinct advantages over other types of vacuum pumps, NASA KSC plans to test one under actual Shuttle vibration loads recorded on the mobile launcher platforms. A simulated mass model of the turbomolecular pump has been built and will undergo preliminary testing on the "shake table." This will be followed by testing of the turbomolecular pump under actual operating conditions. If successful, the project has the potential to significantly enhance the design of mass-spectrometer-based gas detection systems that must operate under high-vibration conditions.

W.R. Helms, 867-4438

DL-NED-32

C.V. Moyers, 867-4614

DF-MA0-2

Low-Cost, Low-Concentration Hydrogen (H₂) Leak-Detection Instrumentation Evaluation

As part of the ongoing hazardous-gas detection system test and evaluation program at KSC, a comparative study of five H₂ sensors from three different manufacturers was conducted. The goal was to find low-cost sensors that could be used for low-level H₂ detection in a gaseous nitrogen (GN₂) environment. These sensors were chosen for evaluation after a market survey of H₂ sensor, and manufacturers' claims indicated these instruments to be the most promising. Two of them, Rexnord and Delphian sensors, are designed primarily for use in the lower-flammable-limit range of 0% to 4% H₂ in the air. The third, a portable sensor manufactured by Bacharach, has an

overall range of 0% to 1% (in the air) in three range settings; and the Bacharach was tested on the highest range (0% to 1%) setting.

These leak detectors are of a type known as catalytic-combustion gas detectors. The detector consists of two precision resistors making up one-half of a Wheatstone bridge circuit. One of the resistors, called the reference element, is computer matched to the other to compensate for fluctuations of ambient temperature, power-supply voltage, etc. The other, called the active element, is coated with a catalyst material containing platinum and other substances. These resistors are powered to maintain a temperature of 750°C. In the presence of H₂, the catalyst causes the familiar reaction $2H_2 + O_2 \rightarrow 2H_2O + \text{heat}$. The heat changes the resistance of the active element and unbalances the bridge, causing current to flow. This current flow is a linear function of the H₂ concentration, and is measured and amplified to provide a remote signal. The signal is then fed into a strip-chart recorder to provide a hard copy of the results and into a digital voltmeter for direct readout.

Since most of the areas of interest are purged by an inert gas such as nitrogen (N₂) or helium (He), makeup oxygen (O₂) must be supplied to the sensor for proper operation. A vacuum pump is used to draw in both sample and air through flowmeters, which are adjusted to give equal parts of sample and air.

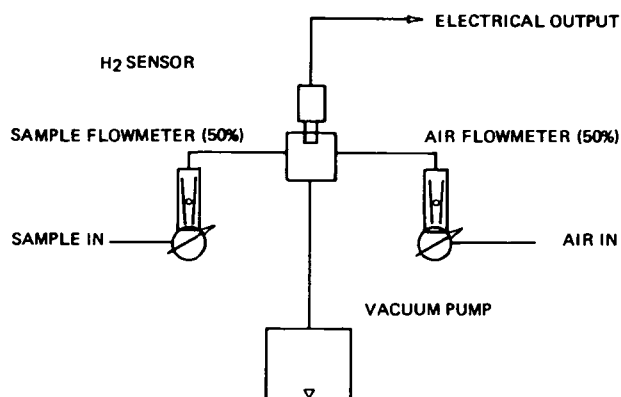
This ensures at least 10% O₂ at the sensor, enough to oxydize 20% H₂. The sensor is calibrated by putting a known concentration into the sample line at the proper flow rate, and adjusting the sensor output accordingly. KSC has used this setup throughout the Shuttle program and found it highly satisfactory.

Zero gas was high purity N₂ and span gases were high purity H₂ in N₂, analyzed. All instruments sampled the same gases at each stage of the test via a baffled mixing chamber with multiple sample ports. The evaluation included

tests for zero and span drift, accuracy, precision, linearity, interference gases, and response times. Interference gases include all combustibles. Further evaluation data are available upon request.

W.R. Helms, 867-4438

DL-NED-32



Remote H₂ sensor operation.

Ambient Influences Upon the Sybron/Taylor Oxygen (O₂) Depletion Detector

The O₂-depletion detector in service at KSC is the Sybron/Taylor paramagnetic O₂ sensor. This instrument measures the current required to maintain static equilibrium of an electromagnetic dumb-bell suspended within the magnetic field of a permanent magnet. In the presence of O₂, an imbalance occurs due to the paramagnetic effect of O₂ on the magnetic field. Thus, the concentration of O₂ present is proportional to the paramagnetic effect, which elicits a measurable change in electrical current to maintain static equilibrium.

The purpose of this evaluation was to provide answers to questions raised by operations and safety personnel concerning unexplained minor fluctuations in the O₂-concentration readings. Since these fluctuations were assumed to have originated from variations in ambient conditions, only the variables of pressure, temperature, and relative humidity

were considered. The obvious first choice for an ambient variable that affects the O₂-concentration readings was pressure, since this instrument measures the partial pressure of O₂. Temperature and relative humidity were, from theoretical considerations, expected to cause only minor variations. However, their effects were also assessed.

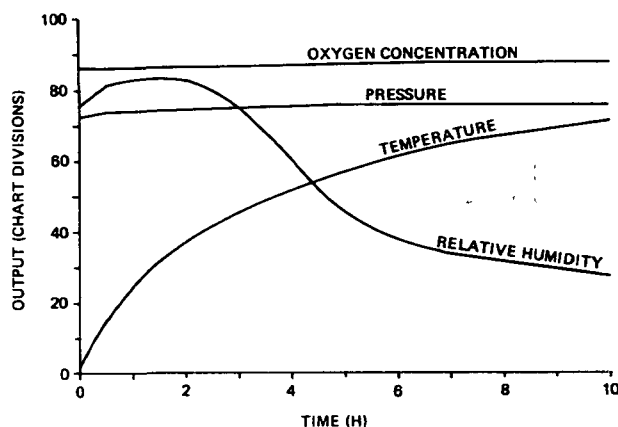
The test results confirmed that, of the ambient variables, pressure, moisture, and temperature, only pressure had a significant effect on the O₂-concentration readings. Where ambient barometric pressure changes are large, a vendor-provided module can be installed to compensate for these changes. This has not proved necessary at KSC.

W.R. Helms, 867-4438

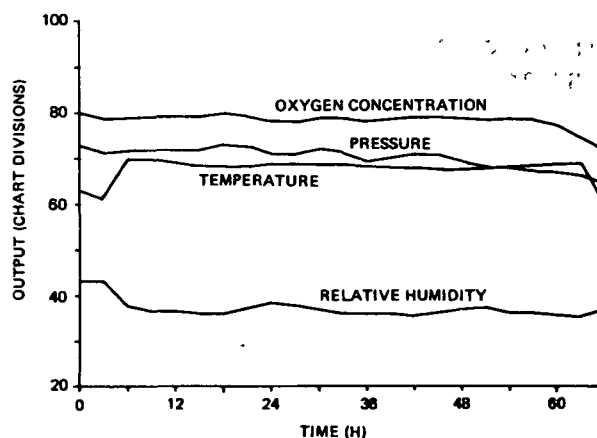
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S.G. Zurek, 867-4449

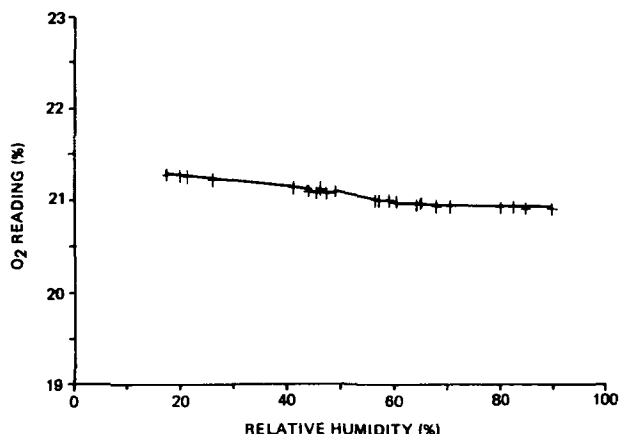
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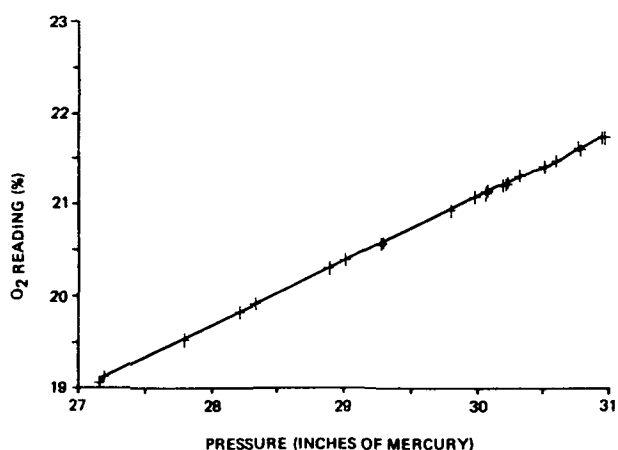
Sybron/Taylor drift test, 4/18 to 19/84.



Sybron/Taylor drift test, 4/13 to 15/84.



Syborn/Taylor humidity sensitivity test, 4/24/84.



Sybron/Taylor pressure sensitivity test, 4/19/84.

Low-Oxygen-Concentration Detection

Inert gases are used extensively at KSC and in the public domain to produce oxygen-deficient atmospheres for laboratory work, for creating special gas mixtures, and for various other applications. In response to a need for a simple, reliable, and inexpensive way to detect oxygen deficiencies and indicate this hazard to personnel, a study was conducted by Niagara Scientific, Incorporated, of Syracuse, New York, to determine if an oxygen-depletion gage that uses no power supplies could be devised. Independence from a power supply would eliminate the concern that a hazardous condition would go undetected due to supply failure,

passiveness would offer ease of use, and a more affordable device might encourage greater usage. No such device exists at present.

Numerous oxygen-dependent phenomena in chemistry, physics, and biology were examined. Specifically, leucodyes, oxygen-carrier color indicators, polymerization, electrochemical, permeation, osmotic pressure, Cartesian diver, density, surface tension, nonstoichiometric oxides, mechanical, Piezoelectric, magnetic, semiconduction, fluorescence quenching, adenosine triphosphate detection, and bioluminescent immunoassay concepts were evaluated. A number of these show good potential for utilization in such a device. In some cases, considerable groundwork would be needed as part of programs to apply these phenomena to working instruments. A few, however, are relatively simple in concept and could be tested for feasibility rather quickly.

The advantages and limitations of each of the schemes disclosed were given, as well as recommendations for development. The most promising concepts involved differential diffusion of oxygen and nitrogen across membranes and magnetic properties of oxygen utilizing fluorocarbon absorbants. Follow-on efforts are being pursued for phenomena testing to determine if a prototype is feasible.

R.A. Gerron, 867-4493

SF-ENG

Remote Sensing of Hydrazines

Initial investigation into laser remote sensing technology for remote sensing of hydrazines has been completed by the Jet Propulsion Laboratory (JPL) in Pasadena, California, for KSC. JPL determined the absorption coefficients for three hydrazines (hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine) and their air-oxidation products (methanol, ammonia, dimethylamine, and trimethylamine). Using a laboratory carbon-dioxide (CO₂) laser system, measurements

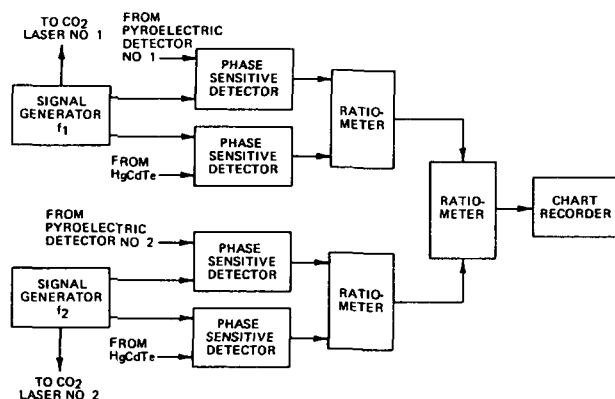
were made that indicate a system could be assembled for field use that would have a sensitivity of 3 to 20 parts per million-meters (ppm-m) for hydrazines and 0.3 to 40.0 ppm-m for their air-oxidation products. Sensitivities of 0.3 to 0.6 ppm-m and 0.25 to 2.0 ppm-m, respectively, were obtained using a tunable diode laser system. The result of this research has led to the design of a laser system suitable for additional research in the laboratory and field.

JPL's design for a continuous wave CO₂ laser system suitable for laboratory and field testing is shown. The key elements of this system are a pair of radio-frequency-excited, grating-tuned waveguide CO₂ lasers, a beam expander telescope, an f/1 receiver mirror, a mercury-cadmium-tellurium (HgCdTe) detector, and analog signal processing electronics. This system should be usable to a distance of 250 meters. JPL is building this system for KSC and expects it to be available for field testing around April 1985.

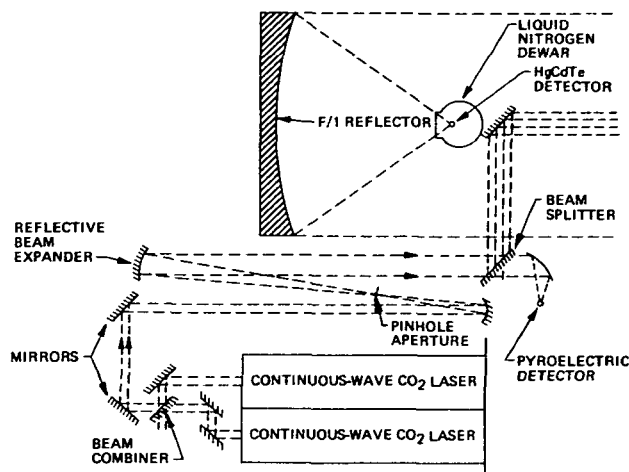
JPL will continue research to improve system design and will field test the system. Also, KSC will use this system to develop an automation scheme for such a laser system so that it may be used more easily in the field.

P.M. Rogers, 867-3842 DL-DED-32

M.M. Scott, Jr., 867-3086 DL-DED-32



Block diagram of the optical layout for the CO₂ laser remote sensor.



Block diagram of the data processing system for the CO₂ laser remote sensing system.

Hydrazine Personal Dosimetry

The objective of this project is to develop a dosimeter system capable of measuring hydrazine and monomethylhydrazine at a dose rate of 100 parts per billion-hours. In particular, passive systems that could be worn by individuals are being investigated.

Space Shuttle operations often require that a large number of personnel work in areas in which the possibility of hydrazine leaks and spills exists. In the event of a hydrazine release, it is desirable to be able to determine the exposure of affected personnel. Currently, no suitable technology exists for this task.

Available commercial and experimental dosimeter badges are being investigated by the Naval Research Laboratory, Washington, D.C. Recent studies of an experimental badge manufactured by GMD Systems, Incorporated, of McMurray, Pennsylvania, indicate that use of a passive-sampling, liquid-sorbent badge for a dosimeter may be feasible. Performance will be determined in terms of lowest detection limit, accuracy, specificity, and long-term behavior. Both laboratory testing at the Naval Research Laboratory and field testing at KSC is being conducted. Different membranes, liquids, and solid sorbent materials are being evaluated. Appropriate analytical

techniques for the different sorbents are also being developed.

W.R. Helms, 867-4438

DL-NED-32

Evaluation of Commercially Available Hydrazine Detectors

The objective of this project is to test and evaluate current commercial instrumentation and determine its suitability for monitoring hydrazine at KSC. This evaluation will provide information necessary to select the best available sensor. It also will provide a benchmark for comparison with future instrumentation.

The toxicity and large quantities of hydrazines used in the Space Shuttle Program require that special precautions be taken to ensure personnel safety. These precautions include routine hydrazine monitoring at parts-per-billion levels. Fragmentary and conflicting information about sensor performance made selection of the appropriate instrumentation difficult.

Five pairs of commercially available, toxic-level hydrazine vapor detectors were compared during a side-by-side laboratory test program at the Naval Research Laboratory in Washington, D.C. The performance of the instruments was determined under identical conditions. Special gas-handling manifolds, analytical techniques, and test procedures were designed for this evaluation. The instruments were tested for span stability; response and recovery times; precision and accuracy; humidity, temperature, and interference effects; and general operational performance.

Inadequate instrument design and manufacturer's quality control problems delayed the testing and interfered with the execution of the test program. None of the instruments was free from defects, and none met all the NASA requirements. Each instrument is ranked compared to the other instruments for

each test. If the performance is similar, they are given the same number score. The lowest value reflects the best overall performance in the tests. Performance characteristics in some areas were not applicable (NA) to the instruments or not tested (NT) because the instruments were not operational during this phase of the testing.

W.R. Helms, 867-4438

DL-NED-32

Performance Tests	Inter-scan	MDA 7080	Energetic Science	MDA Moni*ox	MDA Autospot
Functionality, maintenance	2	2	1	3	2
Zero stability	2	1	2	1	1
Span stability	2	1	1	NT	2
Hydrazine	1	1	1	3	2
Monomethylhydrazine					
Battery test	2	NA	1	NA	4
Calibration stability	2	1	2	4	3
Warmup time	2	4	2	1	3
Response time					
To 50%	1	3	2	4	3
To 90%	1	1	1	4	1
Sensitivity					
Lower limit	1	2	1	3	3
Upper limit	2	1	2	1	1
Precision	1	2	1	3	3
Accuracy	1	1	1	3	2
Linearity	1	2	1	1	1
Relative humidity effects	2	2	1	3	2
Interference effects	2	1	3	4	1
Temperature effects	2	1	3	2	1

Note Numerical rating of 1 indicates the best performance

Summary of test results.

An Evaluation of Hydrazine Detectors Based Upon Emerging Technology

The objective of this project is to test and evaluate technologies suitable for monitoring hydrazine at the parts-per-billion level. The three promising technologies are:

1. Chemically-doped paper tape
2. Chemical derivatization followed by chemiluminescent detection
3. Photoionization

The results of a prior evaluation demonstrated that none of the existing tech-

nologies for hydrazine detection meets NASA objectives for reliability, stability, and selectivity. Therefore, new, yet unproven technologies are being investigated. Three technologies are under consideration by the Naval Research Laboratory, Washington, D.C.

1. The results of a previous evaluation showed that chemically-doped paper tapes are capable of selectively detecting hydrazine at the parts-per-billion level. The performance of the associated instrumentation is inadequate. New instrumentation utilizing an improved tape-transport mechanism is being studied to determine its potential. The performance of tapes from different vendors is also being evaluated, with particular emphasis placed on the tape used by the British Ministry of Defense.
2. A method of sampling hydrazine by first reacting it with acetaldehyde and then detecting the reaction product has been developed by Thermo Electron Corporation of Waltham, Massachusetts. Preliminary studies with hydrazine show that the instrument possesses excellent linearity and accuracy and has adequate sensitivity. The Thermo Electron Corporation instrument is being evaluated to determine its limit of accuracy, precision, and long-term reliability for the detection of monomethylhydrazine. The performance of the system using different derivatization reagents is also being determined. This technique is being studied to ascertain if a portable instrument could be constructed using a portable chemiluminescent nitric oxide detector.
3. Photoionization appears to be a selective method for hydrazine

detection due to the low ionization potential of hydrazine. Preliminary work with hydrazine and monomethylhydrazine shows that the technique possesses the necessary sensitivity and dynamic range. In addition, this method appears particularly attractive for use in space operations. A portable photoionization detector will be modified and evaluated for use as a hydrazine detector.

W.R. Helms, 867-4438

DL-NED-32

Large-Volume Area Fire-Detection Instrumentation

The detection of small, slowly developing fires in a large space such as a high bay area is a difficult task with existing detection equipment and methods. KSC has several such areas used in the preparation of Shuttle cargo satellites, which often contain unusual fuels to further complicate the problem. A Small Business Innovative Research Program request for a proposal to develop a means to detect incipient fires in a large-volume area resulted in a contract with Spectra Research Systems of Huntsville, Alabama. The report was received by KSC, and a recommendation to enter a Small Business Innovative Research Program phase II contract with Spectra Research Systems was prepared to complete the development of the combination ultraviolet/infrared detectors. These detectors, in combination with a microprocessor-based fire alarm control panel, hold promise of providing an economical automatic detection system for use by NASA and others with similar large-volume spaces.

R.W. Hamilton, 867-2712

DD-FED-22

Structures and Mechanics

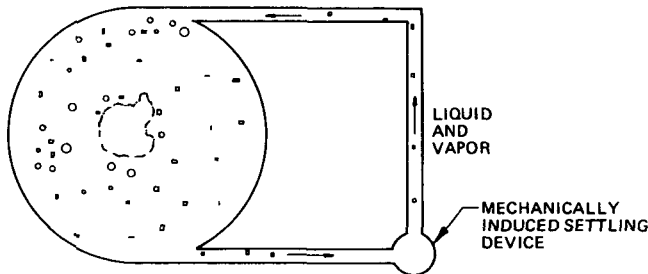
Mechanically Induced Settling Technology

The purpose of this effort is to determine if it is possible to build a modular mechanical device between two tanks in space and perform liquid transfer from one tank to the other in zero gravity. Successful liquid-settling and -transfer tests were performed at zero gravity on a KC-135 aircraft. The test device was a small cylindrical tank filled with a helical-shaped screen that augered liquid out of an outlet tangential to the cylinder wall. The success of this test led to the need to develop a modular mechanical device between two tanks.

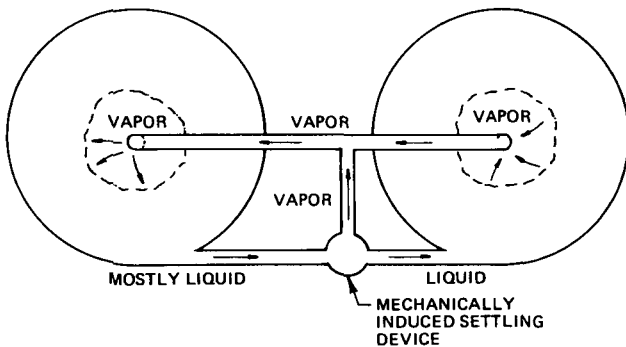
Standards is computer modeling two-phase vortex motion in a cylindrical tank at zero gravity to determine if this is theoretically possible. An idealized model has been developed, and an overall momentum balance has been made that shows that vortexing can be established and flow initiated. The startup configuration and pumpdown configuration that appear theoretically possible are shown. The mechanically induced settling device will probably have characteristics of a pump and a blower. Initial vortexing using gas was modeled, but there was insufficient energy to start the vortexing motion. If the computer model shows the concept is possible and transfer time is reasonable, KSC will build another test model to verify computer model results.

F.S. Howard, 867-3202

DD-MED-4



STARTUP CONFIGURATION



PUMPDOWN CONFIGURATION

Mechanically induced settling technology (transfer configurations).

The approach to achieving phase separation in the modular system is to use vortexing to make liquid move against the tank cylinder wall and gas move to the center; the National Bureau of Stan-

Sensors and Controls

Putting Aerosol Particle Monitors to Work in the Field

Aerosol particle monitors are typically used to monitor cleanrooms to ensure proper levels of cleanliness are maintained. An example is the payload changeout room at Shuttle Launch Complex 39, which is a class 100,000 cleanroom. Monitoring is necessary to control and maintain this environment in order to prevent payload contamination.

There were two critical constraints requisite to the system design. Equipment at this location:

1. Must be hazardproofed to class I, division I, group B.
2. Must not be a source of, nor susceptible to, electromagnetic interference.

Additional design requirements included:

1. An interface with the launch processing system, which is a specialized, launch-complex-wide, computerized data-acquisition and control system for real-time display in the Launch Control Center's firing rooms.
2. Automated data logging and report generation.
3. Mobility to sample various locations.

These problems were resolved by designing the system shown. It includes a commercially available particle-monitoring system consisting of a laser-based sensor, a sample pump to draw the air samples, and a controller for data processing.

The controller outputs data via a serial RS-232C interface, which was not compa-

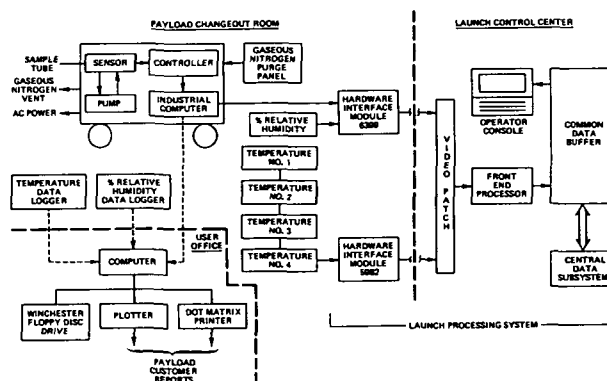
tible with the launch processing system. Therefore, an industrial computer was included to convert the data into a format compatible with the launch processing system and to log the data onto a magnetic tape cartridge. All of this equipment was mounted in a mobile cart that was electromagnetic interference shielded, sealed, and purged with gaseous nitrogen for hazardproofing.

Data for one week can be logged onto the tape cartridge, which is then removed and loaded into a desktop computer in the user's office area. Software was developed that automatically generates graphs for reports. In addition, miniature data loggers are also provided to measure temperature and relative humidity and to store the data in semiconductor memory. These data can also be directly downloaded into the desktop computer for report generation.

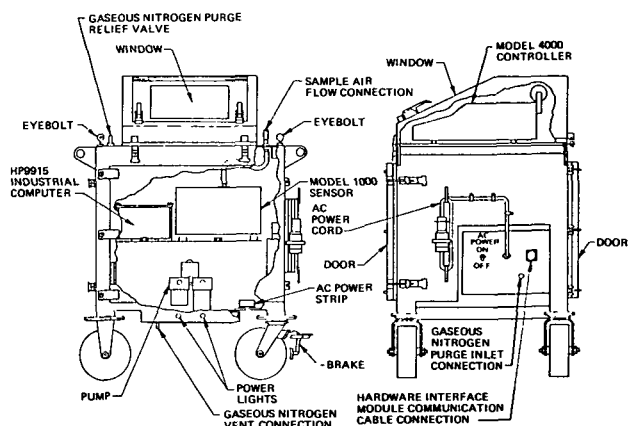
The system is currently installed at Pad A. The first operational use is scheduled for Shuttle mission 51C.

W.R. Helms, 867-4438

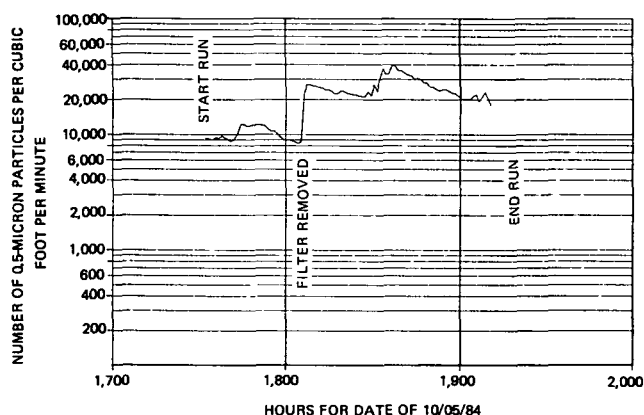
DL-NED-32



Particle counter aerosol sampling system block diagram.



Portable aerosol sampling unit elevation.



Sample: airborne particle counts.

Flow Metering by Laser/Fiber-Optic and Vortex Shedder Devices

In measuring flow rates, especially in the field of cryogenic and hypergolic fluids, many problems are encountered; and better methods and devices are needed with respect to effectiveness, data collection, quality, reliability, survival, installation, retrofit, and maintenance. NASA KSC entered into an arrangement with the University of Florida to investigate the many methods that are and have been used in flow metering, to evaluate them as to their good and bad characteristics, to select the most promising ones, and, with input from KSC, to develop better instrumentation than is available today.

To carry out this task, a thorough review of the literature giving the known main characteristics of these devices,

including their limitations, was undertaken. The resulting information is divided into nine categories: rotating mechanical meters, differential pressure meters, insertion meters, electromagnetic meters, ultrasonic meters, laser doppler velocity meters, fluidic oscillators, vortex shedders, and centrifugal metering pumps.

After careful evaluation, it seemed that the latter four categories showed the most promise and that, through both theoretical and experimental investigation, modification can result in improving the state of the art, and, thereby, the flow metering capability. It was decided to use a laser beam directed into an optical fiber. The fiber is mounted across a flow field in various configurations and made to oscillate by the flowing fluid. The characteristics of the beam emerging from the optical fiber are analyzed as to any changes in flow velocity and/or mass flow rate.

A flow loop was constructed for experimentation and flow-to-fiber-optic-instrumentation correlation. A spectrum analyzer is used to look at the emerging frequencies (some background, some from the pump and auxiliaries) and then at the peaks produced by the flow-induced vibration of optical fiber.

If desired, all the background frequencies and the frequencies produced by other phenomena besides the vibrating fiber can be filtered out, leaving only the desired signal for proper evaluation. Preliminary experiments demonstrated that the fibers will oscillate in the fluid stream, the amplitude and clarity of the signal depending upon the fiber diameter, configuration, and mounting procedures. Peaks are produced by the vibrations of the fiber, and hard copies of the spectrum lend themselves to analysis and, it is hoped, to eventual interpretation and correlation with flow rates and flow velocities.

For the vortex shedder devices, a water loop and an air loop were designed and constructed. The loops were capable of making visible the vortices produced,

counting the number as a function of time, and determining the flow rates, the amplitude of the pulses, and their time-strength configuration.

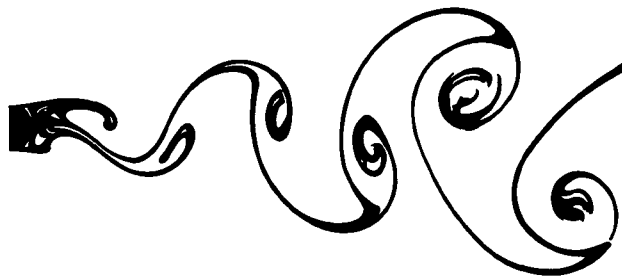
Preliminary results indicate that the position of the pressure pickup can increase the sensitivity and purity of the signal. The design of the shedder bar controls the above two main characteristics and the linearity, making the flow rate proportional to the count rate and the total integrated flow proportional to the total count of pulses or vortices.

Further investigation will be carried out on shapes and sizes of shedder bars as to strength and clarity of signal, linearity, and accuracy and applicability. Combinations of shedder bars that could conceivably amplify the signal or vortices through mutual interaction will also be investigated.

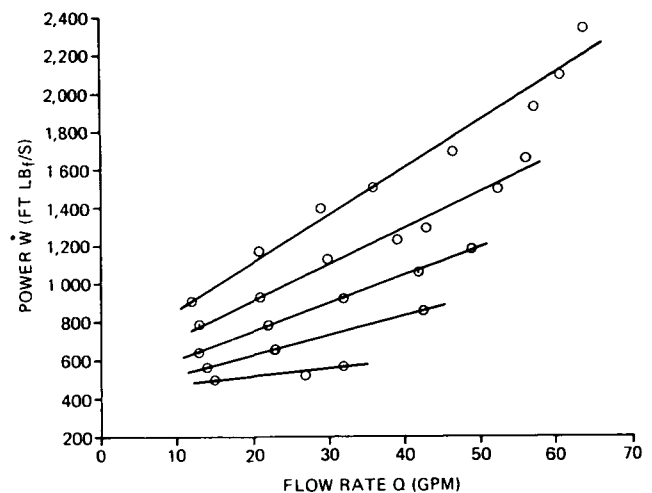
A variation of the above-described method is the fluidic oscillator, which can have many applications but, it seems, also could be used as a flow metering device having no moving parts and giving pressure pulses, which can be translated into flow rates and total quantities of fluids that have flowed through a conduit. Both of the above methods permit the attachment of the instrumentation on the outside of the pipe walls so that the electronics do not come in contact with the fluids to be measured.

R.M. Howard, 867-3366

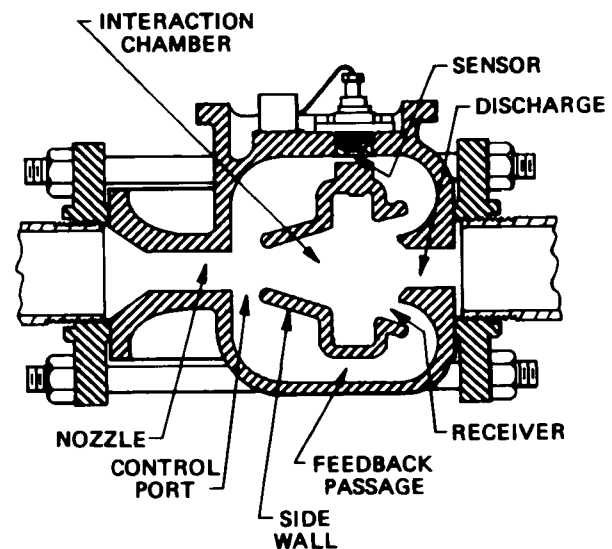
DL-DED-3



Vortices from shedder bar.



Pump meter performance.



Cross section of fluidic flowmeter.

Liquid Level Instrumentation Using Gamma Ray Sources

In many laboratory investigations and industrial and space applications, it is necessary to know the liquid levels of substances in storage, transfer, or fuel tanks. These measurements may be needed under both static and dynamic conditions. Some methods are available, but none of them has been found to be completely satisfactory; and serious problems arise in measuring the liquid levels or quantities of liquid in two-

phase mixtures of cryogenic fluids and highly corrosive substances like hypergols.

NASA KSC entered into an arrangement with the University of Florida to conduct an in-depth study of possible methods for liquid level detection, to evaluate them, and then, after selecting the most promising approaches, to attempt modifications that would result in better instrumentation than is available at this time.

After carefully evaluating the literature, the findings were divided into 16 groups: heated (or cooled) thermocouples, resistive thermal devices, thermal dispersion, ultrasonic devices, differential pressure devices, capacitance devices, conductance devices, time-domain reflectometry, radio frequency probes, microwave devices, pulsed laser fiber optics, vibration probes, bouyant force devices, weighing tanks, pressure-actuated devices, and gamma ray probe devices.

After carefully evaluating the above possibilities with regard to operational effectiveness, reliability, data quality, lifetime, installation and retrofit, performance history, and cost and then rating them on the basis of 10, maximum, the following results were obtained: gamma ray probes, 9.8; heated thermocouples, 9.3; ultrasonic (torsional and extensional), 7.8; and so on down to radio frequency probes, 4.0.

Based upon these analyses, the gamma ray probe devices, or gamma ray densitometers, were selected for further investigation. Very weak sources of Am^{241} , Co^{60} , and Cs^{137} (weak enough to be carried safely in one's pocket) were selected for the experimental work.

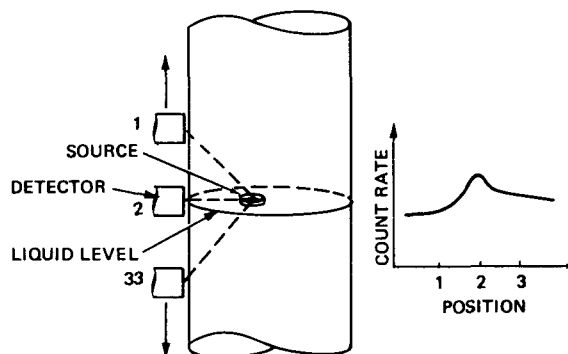
Glass and Plexiglas configurations filled with water or water-and-air mixtures were designed and constructed, having, in some cases, a tube inside as a liquid depressor. One of the sources was attached to a float, and the radiation from it detected by detectors both above and below the source.

in preliminary work, could be detected with a high degree of accuracy under both static and dynamic conditions.

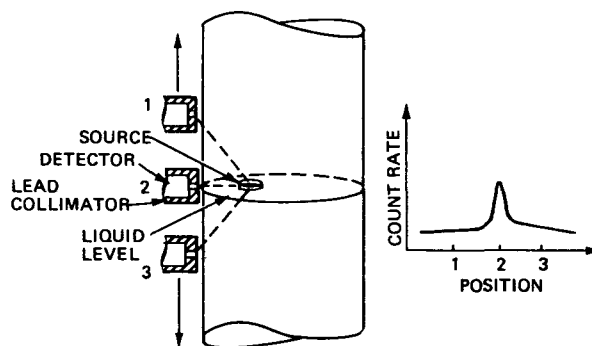
The detected liquid level could be displayed on a computer screen showing the physical arrangement and a curve. Adjusting the response time could average rapid level variations or give the instantaneous result. For various tank configurations, such as spherical, the source movement can be constrained (liquid depressor tube along the wall) to keep the source and detector in close proximity, thus allowing the use of very weak radiation sources. Some thought has been given as to the application of this method to zero-gravity environments encountered in space applications, and the basic method (with some modifications) seems adaptable to those requirements.

R.M. Howard, 867-3366

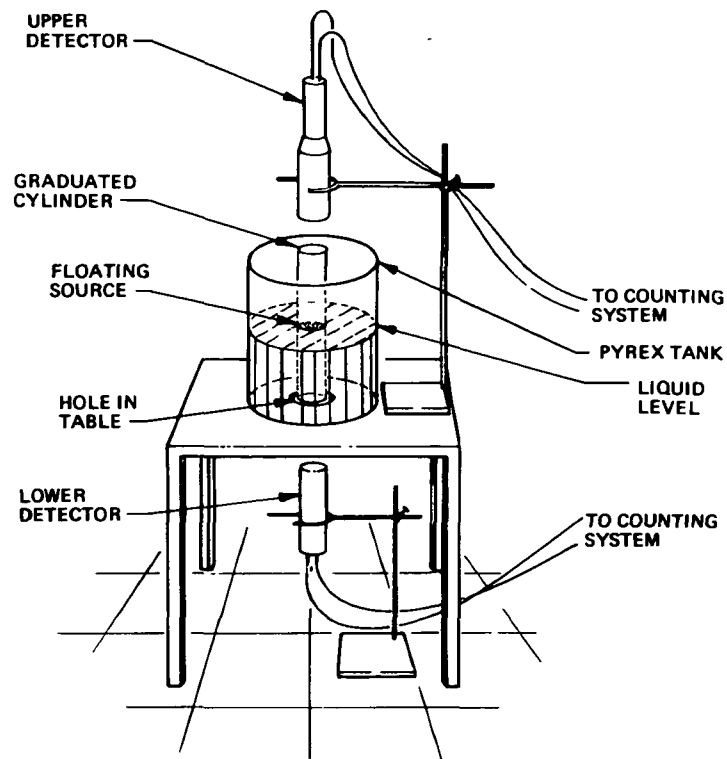
DL-DED-3



Scanning side detector – uncollimated.



Scanning side detector – collimated.



Experimental setup simulating a ground tanking system.

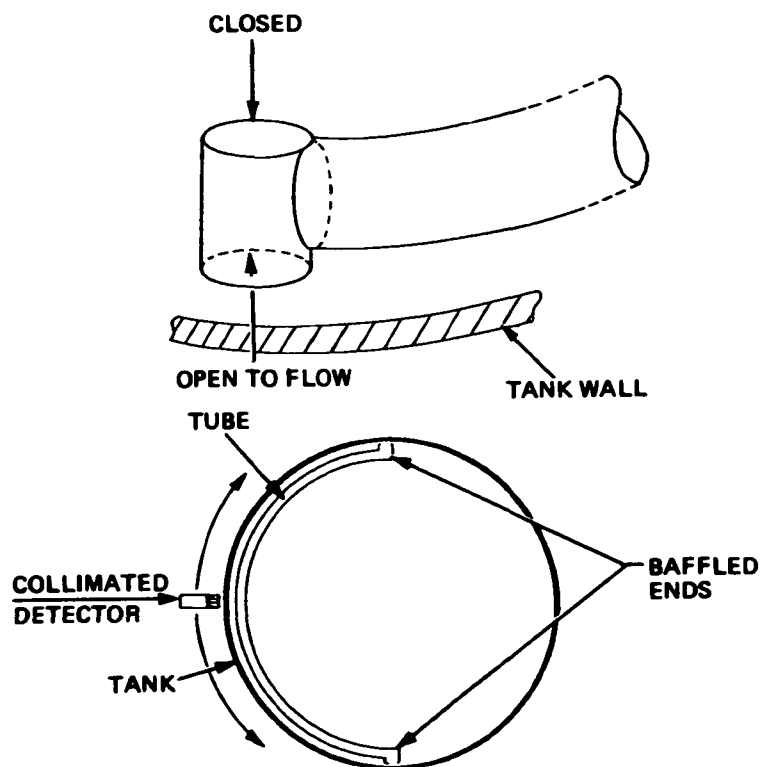


Illustration showing baffling.

Computer Sciences

Artificial Intelligence Research

The liquid oxygen (LO₂) expert system (LES) is an application of artificial intelligence programming to Space Shuttle launch operations. Its objectives are to detect and diagnose failures that might occur in the main propulsion LO₂ loading system during critical prelaunch operations.

Three software elements, a knowledge base, a constraint mechanism, and a diagnoser, comprise the LES. Information that defines and describes the control system is captured in the knowledge base. Each component in the control system is represented by a frame in the knowledge base, whose ultimate size will be approximately 2,000 frames. The conductivity of the circuits, pneumatic paths, and fluid paths are represented, as well as specific characteristics of the individual components and the functional relationships between components.

Malfunctions within the control system cause deviations from the relationships described in the knowledge base and signal a constraint failure. When a constraint failure occurs, the offending measurement is identified, and the diagnosis operation is initiated.

The diagnoser must then determine the single failure within the control system that is the cause of the measurement deviations. The diagnoser performs its task by searching through a space of possible component states to find, if it can, a single bad component; or, failing that, a list of possibly bad components. The search space is pruned by a series of thought experiments that determine the measurement values pertinent to the situation. The generality of this approach makes it possible to centralize the information about the subject control system entirely in the knowledge base and include only general

troubleshooting logic in the software (thus, the artificial intelligence connotations).

A prototype LES has been constructed by a team of scientists and engineers from the Mitre Corporation and NASA KSC. This system reads data from a simulated real-time data bus and attempts to analyze it. The output is in the form of written reports similar to those produced by system engineers. LES identifies single-point failures (when it is possible to do so from the input data) and performs as well as, or better than, experienced system engineers.

It is planned to continue this research for 1 more year. The goal is to interface the LES to real-time data to allow online analysis during launch operations. Improvements in analysis speed and user interface also will be made.

J.R. Jamieson, Jr., 867-0790 SE-FSD

C.I. Delaune, 867-5020 SC-LPS-2

Communications

Operational Intercommunication System - Digital (OIS-D)

KSC is in the process of implementing a third-generation OIS to meet the Center's future Space Shuttle and payload communication requirements. The new OIS-D will utilize state-of-the-art digital technology to implement two 500-channel, multiuser, conferencing networks interconnected with fiber-optic trunks. All normal audio processing and conferencing will be performed in the digital domain rather than with the usual audio circuitry, thereby preserving the system signal-to-noise ratio established by the audio quantization process performed in the user end instrument. Extensive user interaction with the system allows for essentially instantaneous system reconfiguration to meet test and checkout requirements of the Space Transportation System.

The new OIS-D is a noded system with the nodes placed at locations of greatest use and activity. A central hub, or system center, serves to interconnect the nodes at a 45-Mb digital data rate using fiber-optic cable and standard fiber-optic data terminals.

The system will support an unlimited number of users using several styles of end instruments that are electrically compatible with each other but are tailored to specific user requirements with respect to the man/machine interface. All communication to and from the end instrument is via the nodes and is in the form of a digital 130-kb stream containing multichannel audio and signaling information.

The system configuration, access, and overall performance is controlled and monitored by embedded software-controlled processors at the nodes and at the system center. The entire system is powered from several battery plants lo-

cated at critical nodes and capable of operating the system in case of total commercial power loss.

D.D. Lovall, 867-4548

DL-NED-1

F. Byrne, 867-4046

SC

High-Speed Digital Multiplexer/Demultiplexer Development

To make maximum use of fiber-optic cables being installed at KSC, NASA has been exploring techniques to multiplex data links for transmission over the fiber cables. Toward that end, a 50-Mb/s multiplexer/demultiplexer engineering development unit (EDU) has been built under contract with Martin Marietta Corporation for NASA KSC. The primary goal of the EDU was to test the feasibility of multiplexing low-speed data into a high-speed data link. The EDU consisted of a multiplexer with pulse-code-modulation (pcm) input card, burst input card, and a multiplexer card. The demultiplexer portion of the EDU consisted of a 50-Mb/s bit synchronizer card, pcm output card, burst output card, and a demultiplexer card. Both the multiplexer and demultiplexer sections of the EDU are contained in the same chassis for cost and ease-of-testing reasons.

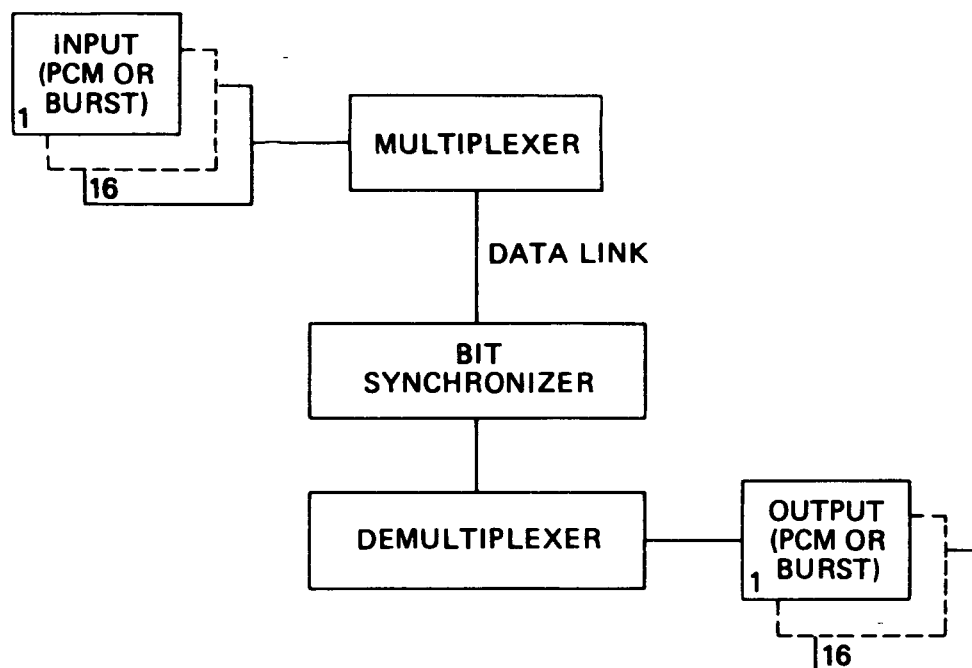
The pcm links were tested at various data rates between 1 kb/s and 2 Mb/s. Up to three links were multiplexed together at one time into the composite 50-Mb/s signal. All design objectives were achieved in the EDU testing with no major problems in technical design.

Work is continuing on the 50-Mb/s multiplexer/demultiplexer with concentration on the packaging and printed-circuit layout for the backplane and the pcm cards. Development of the EDU multiplexer and demultiplexer cards as well

as the synchronizer card resulted in printed-circuit layouts. This was necessary because of the high-speed requirements. This continuing work will result in a prototype unit in late 1985.

T.L. Herring, 867-3843

DL-DED-32



Block diagram of 50-Mb/s multiplexer/demultiplexer.

Materials Analysis

Invar Pipe Weldments

Invar is an iron-nickel alloy (36% nickel) with a low, stable coefficient of thermal expansion, which has been used successfully for cryogenic service for many years. It has been used at KSC for over 15 years. A length of the vacuum-jacketed pipe from the original cryogenic system at Launch Complex 39 was removed for evaluation. Six samples from the longitudinal and the circumferential welds were selected for analysis and evaluation. A 44-inch-long segment of the pipe, between circumferential welds, was subjected to hydrostatic testing until it failed. The pipe leaked at a crack in the heat-affected zone of the longitudinal weld at two-thirds of the design burst pressure.

Examination of some of these welded Invar pipes revealed welds that did not meet present NASA KSC specifications. All radiographic tests verified by metallography revealed undesirable conditions in the form of lack of penetration, cracks, and microfissures.

Satisfactory Invar pipe welds are presently being made using modified Invar 36 filler metal. The study suggests that the use of Inco 82 filler metal should be limited. In an effort to improve and control the quality of Invar pipe to be purchased and installed to meet current and future cryogenic requirements at KSC, revisions of the specifications for Invar pipe weldments have been completed.

R.A. Dyke, Jr., 867-3400

DE-MAO-3

High-Pressure Oxygen Testing Program

A test method to determine the autogenous ignition temperature of materials

in oxygen up to 1,000 lb/in² has been developed utilizing a pressurized differential scanning calorimeter (PDSC). In this method, a small amount of sample, 12 to 18 mg, is placed in a platinum pan in the PDSC, pressurized to the desired test pressure, and heated at 10°C/min until ignition occurs. (Currently, ignition temperatures obtained by this method are being compared to those obtained using the American Society for Testing and Materials' G-72 method.) Next, the ignition temperature of a material will be correlated with the threshold-level data of the standard NASA mechanical and pneumatic impact oxygen-test methods. If a good correlation is obtained, the PDSC method could be used to batch-test materials for oxygen systems at greatly reduced time and material costs.

C.J. Bryan, 867-4614

DE-MAO-2

Testing For Electrostatic Charge on Materials

Testing of thin films of material for electrostatic properties has been conducted at KSC since the 1960's. The testing was initiated at KSC when a solid at the Delta Spin Test Facility ignited due to electrostatic discharge. Currently, there is a great concern about possible damage to integrated circuits and other sensitive devices.

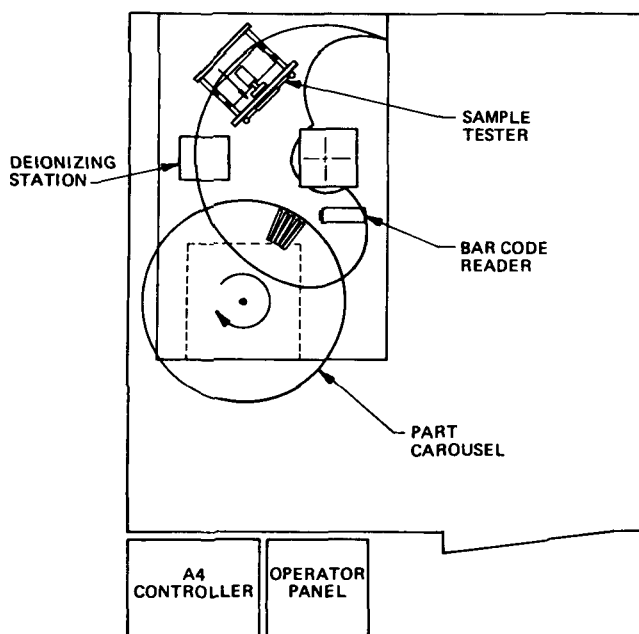
Thin films such as sheet plastics and clothing materials used for workers in critical operations must pass the KSC electrostatic standard: the voltage must drop to 10% or less of the applied voltage within 5 seconds, or below 350 volts in 5 seconds at 45±5% relative humidity and 75-degree Fahrenheit temperature.

At this time, there is an ongoing effort at KSC to compile a material handbook on

a computer file that will list the electrostatic discharge characteristics over a range of temperature and humidity for thin films of various materials. For this purpose, an environmental chamber is being procured by KSC. The chamber will be both temperature and humidity controlled, selectable over a wide range of values. The chamber will be large enough for a robotic work cell. The robotic work cell will perform the testing of and data-gathering from all the samples. The work cell is composed of a robotic arm with end-of-arm toggling, electrostatic testing unit, part-holding carousel, sample holder, bar code reader, and a deionizing station. The electronics that will control the robot and store the data will be housed outside the environmental chamber. The robotic arm proposed for the project is a General Electric A-4 assembly robot having four axes of freedom.

H.M. Delgado, Jr., 867-3367 DL-DED-31

C.L. Springfield, 867-4614 DE-MAO-2



Layout of work cell and arm motion.

Ablative Material Testing Program

A program to evaluate the effectiveness of ablative coatings to protect launch pad ground support equipment from the Space Transportation System (STS) exhaust plumes continued through the first 12 STS flights. Initial tests prior to the first STS launch at KSC were conducted using a 1/16-scale model at George C. Marshall Space Flight Center. This scale-model test aided in the qualification of an ablative coating system for the first few launches. Continued testing during subsequent launches has resulted in the qualification of three coating systems for use at KSC. In this program, test coatings were applied to 1/8-inch-thick, 6-inch-square, zinc-rich-paint-covered steel panels that were then mounted on carrier plates. These carrier plates were then bolted to the zero level of the mobile launcher platform approximately 6 feet from the north edge of the solid rocket booster exhaust ports. After launch, the carrier plates and test panels were returned to the laboratory where the backface temperature of the steel test panels was determined from tempilabels and the weight and thickness losses were recorded. The qualified coatings reduced the backface temperature to less than 150 degrees Fahrenheit, compared to approximately 2,000 degrees Fahrenheit for unprotected panels. Thickness and weight losses were both less than 50%, and, since these coatings are clean ablaters, cleanup to recoat was limited to light brushing. These coatings also exhibit excellent adhesion to the zinc-rich paint on the panels, with adhesive strengths exceeding the strength of the coatings.

B.J. Lockhart, 867-4614

DE-MAO-2

C.J. Bryan, 867-4614

DE-MAO-2

Orbiter Thermal Protection System (TPS) Waterproofing

The Shuttle Orbiter TPS tiles absorb water unless they are protected with a waterproof coating. After a first flight, the manufactured protection diminishes, and the tiles must be rewaterproofed. For the initial test flights, rewaterproofing was done by spraying a solution on the tiles; however, the effectiveness diminished after exposure to rain. The current rewaterproofing method uses injection of a waterproofing chemical into the tiles. Neither method's waterproofing chemical will withstand reentry temperatures. The net effect is that each Orbiter requires rewaterproofing of the TPS tiles after each flight. The procedure is expensive and time consuming.

It was determined through an industry

survey that chemicals that will withstand reentry temperatures are becoming available. Additional effort is planned to develop a new waterproofing system using the new chemicals capable of withstanding high temperatures to provide permanent protection.

Currently, KSC has contracted with Battelle Columbus Labs of Columbus, Ohio, to evaluate, and compare to presently used waterproofing material, a new powder obtained by plasma polymerization of one silicone feed material, hexamethyl disiloxane. In this initial phase of this contract, what is sought is the identification of the potential for this class of waterproofing material, based upon results of characterization and laboratory screening. This study will eventually lead to a waterproofing material capable of withstanding higher temperatures.

F.E. Jones, 867-0728

SE-MSD-11

A Hypobaric Method for Plant Growth in Microgravity

The near-weightless environment of an orbiting spacecraft is an attractive environment for plant studies. Gravity has intracellular to macroscopic effects on plant growth. The ability to grow plants under controlled conditions in a near-weightless environment can provide insight into various plant-growth mechanisms and allows separation of plant-growth responses that are inherent to or are induced by the Earth's environment. To determine its adequacy to function as a culturing system for plants in space, KSC initiated a project to design, fabricate, and test a prototype nutrient-film-technique system.

The main problem associated with designing a hydroponic method for a weightless environment is how to maintain separation of the circulating nutrient solution, needed for plant nutrition and transpiration, and the circulating air, needed for root respiration. The air could be circulated from the cabin of the spacecraft to the roots and back out to the general environment of the cabin. The water must remain in the hydroponic system. Both water and air must be available to the roots simultaneously. A cross section, illustrating the technique employed to accomplish this, is shown. A depression is cut in a plastic plate, and a plastic screen is placed into it. A porous membrane material is placed over the screen and sealed at the edges of the depression. Water from a supply container enters beneath the membrane at a pressure slightly less than the ambient air pressure. The water flows through the interstices of the screen, beneath the membrane, exits at a pressure slightly less than the entrance pressure, and returns to the container via a peristaltic pump. The slight tension on the fluid beneath the porous membrane prevents any

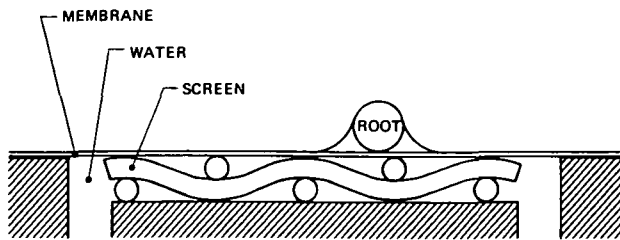
excess fluid from accumulating on the outer surface of the membrane. This contains and controls the water in a weightless environment. Where a root touches the membrane, the adsorptive attraction of the water to the root is strong enough that a film forms in the immediate vicinity of the root. This film, the size of which is proportional to the water pressure beneath the membrane, supplies the plant with its required water and nutrients.

The first plant-growth test with this system was purely qualitative. It was conducted to see if plants would grow at all using the capillary-effect root-environment system (CERES) and to see what physical problems would occur in the system during several days of operation. The plants grew well in the membrane devices and, by visual comparison, were similar in size and morphology to the plants grown in the nutrient-film-technique system. Root hair development in CERES is strong, and there tends to be a lot of root branching. More quantitative plant-growth tests are presently being conducted.

The CERES uses capillary attraction to provide a moist surface from which plant roots can receive the moisture, nutrients, and air needed for growth. Because the fluid behavior is controlled, it is not necessary to seal the plants into chambers. The behavior of the fluid is compared to behavior of the working fluid in heat pipes. A comparative growth test indicates that CERES is a useful method of hydroponics for plant-growth studies in microgravity, as well as on the ground. Tests of the small prototype unit will continue during 1985, and a larger unit will be fabricated and tested.

W.M. Knott, 867-3152

MD-ENV



Cross section illustrating CERES hydroponic method.

KSC Laboratory Sled Head-Restraint System

The KSC laboratory sled is used to study the space adaptation syndrome. The sled has a very wide range of motion capabilities and many different seat orientations; this provides a unique and variable system for studying changes in the human vestibular system.

In the past, the head-restraint systems used in conjunction with the sled were flight hardware provided by the experiment team using the sled for ground studies; therefore, experiments could only be performed by experimentors who owned their own head-restraint system. Due to this fact, it was logical to design and construct a sled head-restraint system that would be adjustable and could meet the requirements of different experiments, thus giving use of the sled to many different experimentors.

The new, multipurpose head-restraint system was designed and constructed by Payload Systems, Incorporated, of Wellesley, Massachusetts. The new restraint system interfaces physically with the existing KSC laboratory sled and provides a light-tight, ventilated environment adequate for the test subjects' comfort and safety. It also provides a two-way intercommunication system compatible with the current sled system and the capability to record horizontal and vertical electro-oculogram measurements using existing Life Science Program preamplifiers. The restraint has the capability to support modular "canopies" that will be designed for specific experiments. It can also pro-

vide triaxial linear acceleration data to the sled's data acquisition system.

The sled head-restraint system is used to study astronauts before flight and the space adaptation syndrome after flight. It is a valuable tool in the study of all vestibular physiology relating to space travel.

W.R. Munsey, 867-4670

CP-FSO

I.D. Long, 867-3165

MD-MED

Life Science Biological Research Program

Recently, the KSC Biomedical Office has initiated research projects in two general areas: plant physiological ecology and environmental microbiology. The plant research program is investigating several environmental factors and their potential interaction with plants exposed to microgravity. A specific study is designing and evaluating a nutrient film system that may be applicable to growing plants in space. The microbiological research program is evaluating selected microorganisms as detoxifiers for chemical wastes and as a renewable source of hydrogen. The research programs at KSC are of an applied nature and will continue to be oriented toward problem solutions that will assist in processing biospecimens at the launch site. These research activities are conducted by degreed scientists with associated laboratory technicians.

The plant research is centered on the varied responses of plants to externally applied physical forces. Of primary interest are the plant responses to changes in gravitational force and the influence of other environmental factors on these responses. Using a recently developed nutrient film system, small electric currents flowing across the root environment are being evaluated as a solution to the problem of disoriented root growth under microgravity. Experiments are investigating the effects of

electric fields and gravitational forces on calcium redistribution, hydroxyproline-rich glycoprotein accumulation, cell wall structure, callose deposition, auxin transport, cytoplasmic streaming, and ethylene biosynthesis. A non-intrusive method for the measurement of plant growth is being developed.

The microbiological research program is focusing on the maximization of hydrogen production rates of selected photosynthetic organisms through environmental, physiological, and genetic mani-

pulations. A hydrogen auxostat system and a fixed-film reactor have been developed and tested. Research into microbial cultures to biodegrade or detoxify potentially hazardous waste materials has been initiated. The initial research problem has been to use denitrifying bacteria to produce nitrogen gas from nitrate/nitrite-rich aqueous wastes. The acquisition of denitrifying cultures that can use one of several inexpensive carbon sources is being explored.

W.M. Knott, III, 867-3152

MD-ENV

Meteorology

Rocket-Triggered Lightning Program (RTLP)

The KSC RTLP successfully supported the Air Force Wright Aeronautical Laboratories and Federal Aviation Administration (AFWAL/FAA) Airborne Lightning Research Program this past summer. The FAA CV-580 aircraft flight operations were conducted from June 11 through August 28, 1984, with support provided by the Eastern Space and Missile Center Weather and Vector Control and KSC RTLP according to the memorandum of understanding between NASA and the Air Force. This program was supported by noted atmospheric researchers at the University of Arizona, University of Florida, State University of New York at Albany, the Naval Research Laboratory, and the AFWAL.

The RTLP plan was that, when a thunderstorm passed over the rocket launch site on KSC (1.2 miles northeast of the Vehicle Assembly Building), the following were performed:

1. A wire trailing rocket was launched precisely when the electric-field mill reading was optimum for triggering a lightning strike to the grounded wire (5 kilovolts per meter, minimum).
2. The FAA aircraft arrived directly over the rising rocket simultaneously with the triggered lightning strike.
3. All electromagnetic characteristics of the lightning events were photographed and recorded.

The FAA aircraft flew around many thunderstorms all across central Florida while waiting for storms to form over KSC. Substantial ground and airborne electromagnetic and current data were obtained from 20 natural lightning (pri-

marily intercloud) strikes to the aircraft. Two of the events may have been natural cloud-to-ground lightning events. RTLP produced eight rocket-triggered lightning events; four of these included lightning return strikes very similar to natural lightning. Significant data were collected by the aircraft and ground instrumentation during these events. The RTLP ran for 40 days from July 11 through August 19, 1984. Nineteen rockets were fired during the four thunderstorms that developed near the rocket site. The triggered-lightning events did not hit the aircraft, even though the aircraft was vectored on target at the site. Many of these events were captured on video tape and film. Preparations are underway to produce a documentary video tape of the summer activity. Shown are three frames from the 35mm (1,000 frames per minute) film exposed on August 11, 1984.

W. Jafferis, 867-0526

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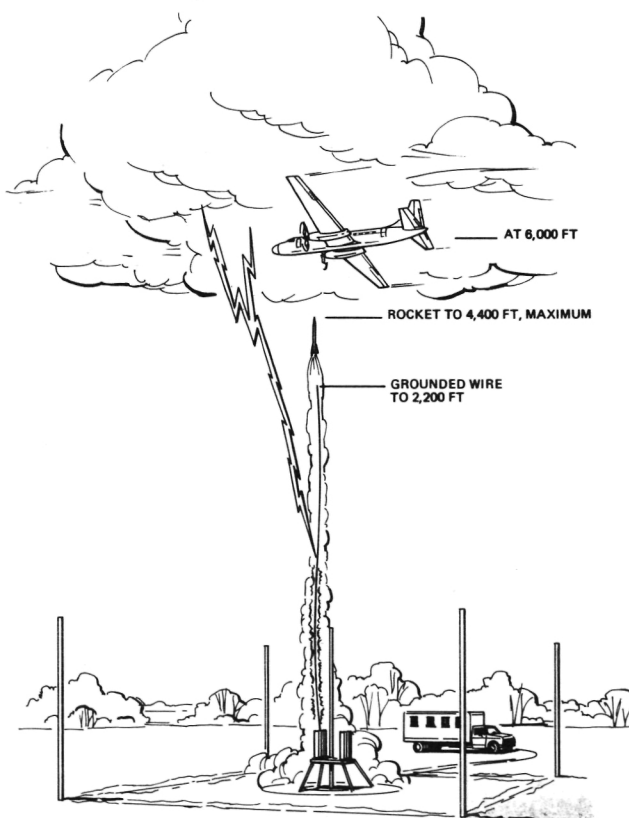
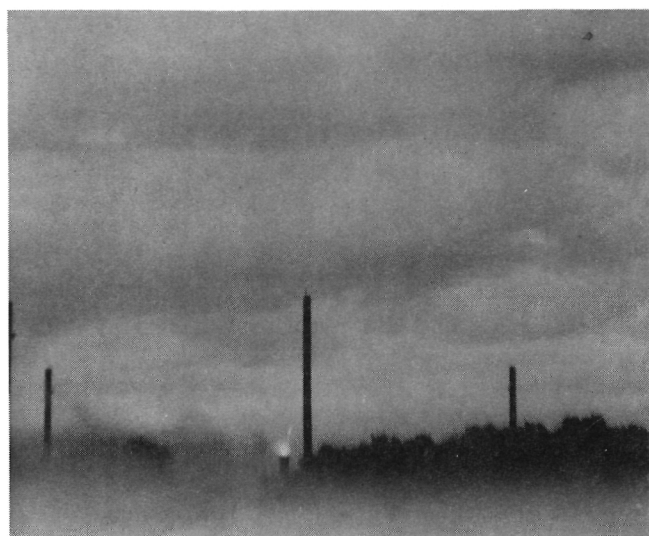


Illustration of RTLP experiment.



Rocket in flight, 19:33:07.08Z.



Lightning incitation, 19:33:09.58Z.

Improved Short-Term Forecasting of Lightning at KSC Based on Surface Wind Convergence

Prior research in south Florida indicated a reasonable likelihood that surface divergence could be used as a short-term predictor of lightning and activity at KSC when storms formed overhead. Convergence was found to precede rainfall, and there was an indication that the magnitude of convergence was related to the amount of precipitation. These relationships varied under different atmo-

spheric conditions. Additional research indicated well defined correlations between radar echoes and cloud-to-ground lightning occurrence. Finally, another study in the same area showed that the amount of lightning is controlled to a degree by the larger scale synoptic controls. On the basis of these studies, it was reasonable to expect that surface convergence was related to radar reflectivities and, hence, cloud-to-ground lightning at KSC, especially when the synoptic scale influences were properly considered.

Data were collected in the summer of 1983, mostly during August and September. Wind data at 12 sites were analyzed at the 54-ft level for surface divergence and streamline patterns. Radar data were obtained from the Daytona Beach National Weather Service radar between 1000 and 0200 hours, Greenwich Mean Time (GMT), from mid July to the end of September, and were processed for maps and time series. Cloud-to-ground lightning data were obtained from the lightning location and protection network in the Cape Canaveral area for the same period to provide maps and time series. Three cases were analyzed in detail.



Triggered lightning, 19:33:10.30Z.

Surface meteorological conditions were continuously monitored by the Automatic Range Meteorological System (ARMS). For this study, 15 instrumented towers at Cape Canaveral Air Force Station and KSC were used. These meteorological stations are concentrated around launch sites and not distributed equitably throughout the area because the primary purpose of the ARMS is to monitor for the location of toxic fumes. Twelve sites provided information at 12 and 54 ft, two sites were instrumented to 204 ft, and one went to 500 ft. Tower data included wind direction and speed, temperature and dewpoint, and atmospheric pressure.

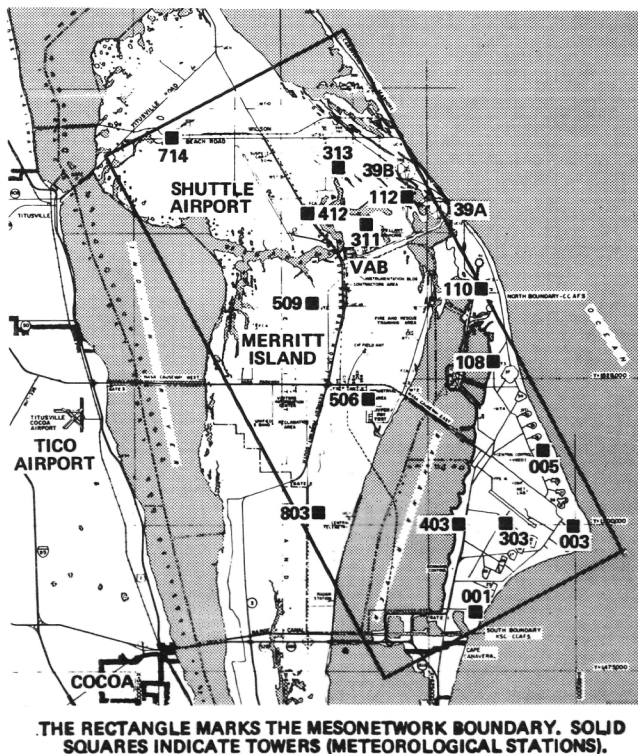
Through the Weather Information Network Display System, the meteorological information is retained on tape and provided on a real-time basis to various users at the Cape Canaveral Air Force Station and KSC. The data were kindly provided to the National Oceanic and Atmospheric Association by the United States Air Force via the Meteorological Data Reduction Section.

For the purposes of this study, the main emphasis was placed on the tower wind data recorded at 54 ft. The surface divergence fields were calculated from 5-min averaged winds. A 6 by 12 grid of equally spaced (2.8 km) points was superimposed upon the original network. Through the use of an objective analysis scheme (Cressman, 1959), the network winds were transformed into a uniform grid of u and v components. The values of the wind components at each grid point were then used to compute the divergence quantities using a centered, finite-difference scheme.

These preliminary studies tend to indicate that it is possible to anticipate the subsequent degree of lightning activity from a measurement of prior low-level wind convergence. They also stress the need for considering not only the mesoscale situation, but the synoptic background in which the mesoscale convective processes are developing. These efforts were continued in the summer of 1984 and are expected to continue in 1985 with an expanded mesonetwork.

W. Jafferis, 867-0526

SO



KSC and Cape Canaveral Air Force Station area.

Thunderstorm Currents

The handling of propellant materials at KSC makes lightning a very hazardous phenomenon. A system that detects the potential for lightning is in operation at KSC; however, the system cannot predict whether the lightning hazard is increasing or decreasing. To do that, the state of the thunderstorm generator itself must be determined.

Some recent developments suggest that this may be possible. Recent research in atmospheric electricity conducted by the University of Arizona Institute of Atmospheric Physics suggests that an electric-current sensor network may be able to track the state of the thunderstorm generator that produces the electricity that results in lightning.

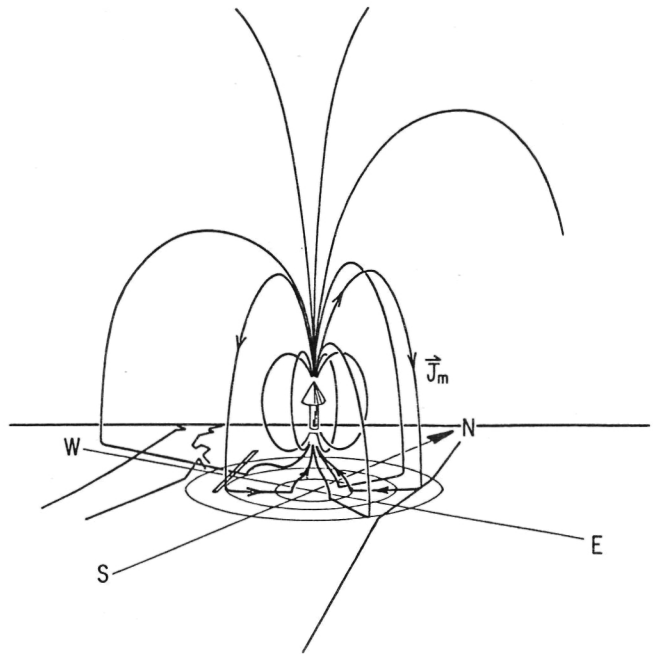
The large arrow in the center represents the thunderstorm generator, while the

contours represent current density streamlines. Since charge is conserved, the streamlines make closed loops. This fact suggests that, from an array of current sensors located on the ground, the state of the thunderstorm generator might be determined. This simplified picture may be complicated by many factors; the best way to determine whether ground-based current sensors can characterize the thunderstorm current generator is by a field experiment.

During this past summer at KSC, the University of Arizona conducted a field experiment of a limited, ground-based, current-sensor network. The network consisted of three thunderstorm current sensors and associated instrumentation. Preliminary results suggest that the sensors have a very high dynamic range compared to that of the existing sensors and can track the condition of the thunderstorm generator from inception to the end of the storm. Initial results are promising, and analysis of this summer's data continues. Further field testing is planned, and a more extensive network of sensors will be tested.

R.P. Wesenberg, 867-4438

DL-NED-31



Theoretical description of typical thunderstorm generator's structure in terms of current density (J_m).

Engineering Management

Shuttle Inventory Management System (SIMS) II

The SIMS II is an integrated, automated data processing system that will provide logistics support to the Shuttle Program in the operations era. Its purpose is to assist management, the operators, and logistics organizations in ensuring that supplies and materials are available as required to support the Shuttle Program.

The system will consist of application and communication software operating on two dedicated Honeywell DPS 8 computers and will be structured around a data base management system. It will feature batch and real-time, online input and queries provided via interactive cathode-ray-tube terminals installed at KSC, Florida; Vandenberg Air Force Base, California; Downey, California; Lyndon B. Johnson Space Center, Houston, Texas; George C. Marshall Space Flight Center, Alabama; Michoud Assembly Facility, New Orleans, Louisiana; Canoga Park, California; Wasatch, Utah; and facilities of participating contractors. The system architecture will provide dedicated support to the SIMS II system with backup capability to ensure system responsiveness.

Employing to the fullest extent possible state-of-the-art data processing and telecommunications techniques, the SIMS II will:

- a. Provide a cost-effective, functionally oriented, real-time, automated, logistics system to manage Shuttle supplies and materials and institutional support requirements.
- b. Provide an online, interactive supply system that integrates the logistics functions of provisioning, replenishment, pro-

curement, inventory management, and transportation.

- c. Provide the operators with real-time visibility of supplies and materials' status needed to manage launch operations so that the work can be scheduled accordingly.
- d. Provide NASA and Air Force management visibility of all Shuttle supplies and materials inventories, whether they are physically controlled by the Government or by designated contractors.
- e. Provide NASA and Air Force management with the capability to measure and evaluate how effectively and efficiently the logistics organizations are performing the supply function.

E. F. Brimberg, 867-4857

DL-NED-1

Configuration Management Data System (CMDS)

Past requirements for NASA's tracking of engineering changes and engineering documentation at KSC have resulted in the development of many isolated and fragmented configuration management systems. This problem is complicated by the fact that contractors have also developed their own independent systems, often with an 80% data overlap to an existing system. Furthermore, previous configuration management systems did not accommodate well the needs of an engineer or manager who required information closely related to, but not identical to, a pure tracking function.

To alleviate this problem, a single CMDS was developed. This system incorporates

the combined data from the twelve earlier stand-alone systems it replaced. Consequently, record redundancy was minimized, data entry manpower was reduced, and consistent reports and data integrity were obtained.

CMDS is an IBM-4341-based system, currently supporting approximately 150 users. It contains about 600 megabytes of information in 400,000 records. The programming language is NATURAL, which is the user interface language for the data-base management software, ADABAS.

In addition to very current relational data-base management software, CMDS has many attributes within its design to benefit both the developer and the

user. Included in these are: extensive permission checking and functional area checks to support a multicontractor environment; table-driven, system-supported edit checks to promote valid data entry for the life of the system; on-line, full-screen data entry; extensive ad hoc query and report subsystems; and a comprehensive set of system-development and data-cleanup software tools.

CMDS became operational in February 1984 and is currently in use by NASA and several contractors including EG&G, Florida, Incorporated; Lockheed Space Operations Company; and Planning Research Corporation.

L.A. Wilhelm, 867-7582

DL-DED-21

Logistics and Expert Systems

Logistics support of advanced space systems will be an expensive and potentially manpower-intensive burden. This is especially of concern given on-orbit considerations, such as for Space Station, where significant manpower resources will be needed for mission operations. In concert with program objectives of increased autonomy to reduce the ground support infrastructure and costs, a research effort is underway to identify promising applications of artificial intelligence and expert systems to logistics problems of the Space Station.

Tasks to date have been concentrated on four areas: expert subsystem specialists, fault isolation and repair, intelligent manuals, and planning and scheduling systems.

1. In the area of expert subsystem specialists, the expert system will monitor, maintain, troubleshoot, and repair various subsystems. Faced with a subsystem problem, the specialist will step through diagnosis, treatment, and, finally, a workaround.
2. In the area of fault isolation and repair, the thrust is to combine fault-tolerant hardware and expert systems technology, resulting in intelligent systems. These could be considered as expert systems, imbedded in equipment. The concept could be extended, resulting in hierarchical hardware. In this case, a hardware system may have several indentured sets of equipment, each of which has its own expert system to monitor, diagnose, and then effect repair. The system has its own

independent supervisory expert that will decide workarounds from a system perspective.

3. A third application area is that of intelligent manuals. This would include complexities ranging from online, interactive reference manuals for operations-and-maintenance procedures and techniques to report generators and, finally, routine form filling.
4. The last system application area being investigated encompasses planning and scheduling, which includes subareas of transportation, inventory management, fluid and propellant management, and maintenance management.

Remaining tasks will identify the most promising of the above application areas and suggest what additional research, if any, should be undertaken.

G.A. Opresko, 867-7898

PT-LMO

Spares Quantification

As man's role in space expands in both scope and duration, NASA is pursuing the development of several advanced space systems. These include the Space Station, orbital maneuvering vehicle, orbital transfer vehicle, space platforms, Space Telescope, and numerous free-flying and mounted payloads. Cost-effective support of systems such as these will be critical.

Supply considerations, including spares quantification, is one element of this support and must be addressed from the NASA operational perspective, which is highlighted by small fleet sizes.

Traditional methods and techniques used by both Government and industry to estimate and budget for logistics resources such as spares are typically based upon large end-item populations. Since these techniques may not be appropriate for relatively small fleet sizes with low component demands or failures, a research effort has been initiated to further explore this area.

Specifically, this effort is directed at problems in forecasting demands for logistics resources. It is widely recognized that resource demands, and their underlying probable distribution, drive the entire logistics system. Most spares quantification models assume a Poisson distribution for the arrival of demands against the inventory system. This equates to a variance-to-mean ratio (of the underlying distribution) of 1. Logistics system performance measures and resource requirements, such as for spares, are based upon this assumption. A review of actual data has revealed that the variance-to-mean ratio is, in fact, greater than 1 for many component parts; and, in addition, the means and variances of items tend not to be stable over time. The ramifications of these phenomena could have significant effects not only upon the ability of the system to achieve estimated support performance, but also upon the projected life-cycle support costs in terms of initial and replenishment spares.

G.A. Opresko, 867-7898

PT-LMO

Material Accountability

Advanced manned space systems will provide a unique challenge technologically as well as from the standpoint of logistics support capability. The requirement to track and status on-orbit inventory and consumables, as well as ground-related logistics support activities, will require responsive and efficient interactive systems.

Several efforts are underway that address automated material accountability. A pilot project utilizing bar-coding techniques has been implemented for equipment inventory management. This is being expanded to include subcomponent status and tracking in a completely closed-loop environment--operations, maintenance, and supply. State-of-the-art techniques for automated material accountability and tracking being developed and used in industry are being reviewed for manned space systems applications.

In addition, camera-vision concepts as well as voice-activated techniques are being surveyed. Evaluations highlighting advantages and disadvantages of applicable technologies will be compiled as part of this study effort. The effort will identify those technology areas, including those requiring further development, showing greatest potential benefit for manned space system use.

G.A. Opresko, 867-7898

PT-LMO

Training and Maintenance Aids

Application of Voice-Interactive Maintenance-Aiding Device (VIMAD) Technology

KSC has completed a study effort with Honeywell, Incorporated, to determine if the elimination of paper documentation is feasible for certain KSC operations by using an improved VIMAD. The VIMAD concept, developed by Honeywell under contract to the Defense Advanced Research Projects Agency, became feasible after development of a video disc that can store thousands of still photos and brief movies to show how to perform maintenance operations. The stored data are recalled and sequenced by voice command to the computerized control center. They are then displayed on a miniature television set that is part of the operator's headset.

After thorough study, a relatively small number of specific applications were judged compatible with a standard VIMAD implementation. It is suggested that this results from the significant differences between KSC operations and those of military maintenance for which the original VIMAD concept was developed.

Suggestions for future research and development are offered in the final report for digital data-base system networking and communications requirements and for portable video-camera system implementation issues. It was recommended that KSC establish a VIMAD testbed for Spacelab processing because changes in KSC operations and maintenance activities that will accompany routine action of Shuttle processing will make VIMAD technologies more attractive and because cost-effective Space Station operations and logistics support will require electronic job aids for mission specialists. These techniques will be more effective than intense, costly training

programs that, no matter how well designed and conducted, cannot provide for unforeseen operation or maintenance requirements. Also, the weight and space penalty that would be paid for voluminous technical documentation may not be acceptable for Space Station. If VIMAD technologies are to be applied to Space Station mission tasks, it is important that planning and technology development begin soon.

J.B. Lansing, 867-4888

SF-SAF-3

Application of Surrogate Travel Technology

KSC has completed a pilot project with Interactive Television Company of Arlington, Virginia, to demonstrate the surrogate travel technology using a computer interacting with a videodisc player to give a random-access pictorial display of all aspects of an intricate facility, in this case, Launch Complex 39A. By utilizing the computer, control is switched to the operator of a joy stick for traveling forward, backward, or side-to-side to any part of the complex. A graphical display is brought up on one color monitor with a cursor to show the operator where he is, and a corresponding actual photograph is brought up on an adjacent color monitor to show exactly what every step along any path would look like, if he were actually there; hence, the term surrogate travel.

KSC is investigating this technology to apply to training and orientation situations to keep from subjecting personnel to hazards or interfering with operations, particularly as the future launch rate increases. The Launch Complex 39A videodisc and equipment are available for demonstration for other applications. Some other areas of possible use

that are being pursued are documentation storage, computer-aided training, repetitive maintenance, and as-built drawings.

J.B. Lansing, 867-4888

SF-SAF-3

Tactical Air Navigation (TACAN) Beacon Calibration

Guidance data are provided by the KSC TACAN system to the Orbiter from post-blackout to within 10 nautical miles of the Shuttle runway. For a period of time, there existed variances between the TACAN data and that observed during actual training flights, shedding doubt on the credibility of the navigational data provided by this equipment. A method was sought for measuring the accuracy of the TACAN beacon to within 0.1 degree.

A TACAN beacon test set was obtained from Sierra Research Division of LTV

Aerospace and Defense Company of and modified to interface with existing digital flight recording equipment. There were two major phases of flight testing. The first phase involved the use of the test set in conjunction with the microwave scanning beam landing system (MSBLS). Flight profiles allowed simultaneous collection of data from the test set and the MSBLS, within the MSBLS volume of coverage. The second phase addressed the full TACAN volume. In this phase's test-set data, precision laser tracker system data and C-Band radar data from a transponder installed on the aircraft were collected.

Special software was developed to correlate tabularly formatted data with data displayed graphically. The close correlation between the reference data from the three sources (MSBLS, precision laser tracking system, and radar) satisfactorily established the accuracy of the TACAN installation.

H. Perkins, 867-4438

DL-NED-31

Technology Applications

Application of NASA Technology for Automatic Location and Tracking of Subjects

The United States Fish and Wildlife Service and other Government agencies have expressed the need for an automatic system for precisely locating and tracking a number of subjects, such as wildlife. In response to such inquiries, KSC has sponsored a study to determine the feasibility of producing such a system using technological concepts used in the space program.

The investigation was conducted in two phases. The objectives of phase 1 were to define system design goals, to evaluate specific candidate location techniques, and to recommend the specific design with the greatest probability of meeting the design goals. The objective of phase 2 was to verify feasibility of the recommended system through operational demonstration of the system's critical components. Upon completion of phase 1, a system was recommended that employs differential-time-of-arrival (DTOA) measurement techniques with narrow-band postdetection filtering and data integration for improving receiver sensitivity. System goals were established as follows:

1. Accuracy: within a 50-meter radius
2. Object transceiver package weight: 500 to 1,000 grams
3. Battery life: 2 to 3 years
4. Transmitter output power: 10 milliwatts, radiated
5. Receiver sensitivity: -120 decibels referred to 1 milliwatt, minimum
6. Operation: automatic

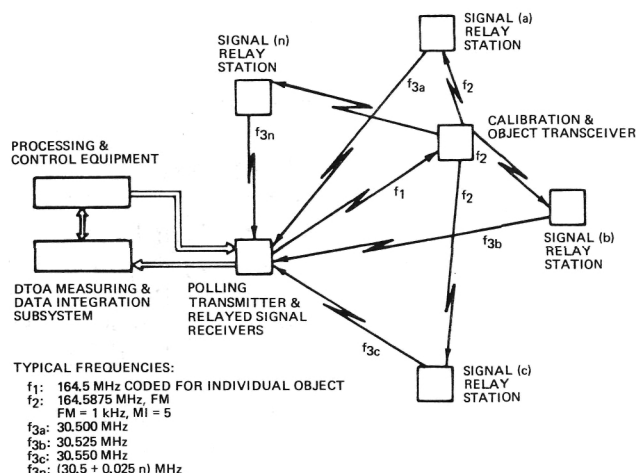
7. Rate of position measurement for individual object: range from 1 minute to 1 month

Selection of the recommended system was based on a study and tradeoff analysis of 12 candidate systems selected from four general tracking system categories: radio-frequency direction finding, navigational aids, time-of-arrival, and satellite systems. Each candidate system was evaluated for capability to meet the seven goals and for cost effectiveness.

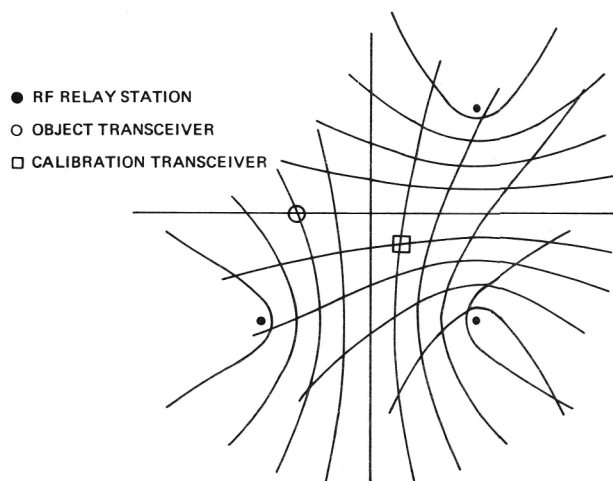
The components of the recommended system are processing and control equipment, DTOA measuring and data integration subsystem, polling transmitter, calibration and object transceiver, signal relay stations, and relayed signal receiver. The calibration and object transceivers are polled in a predetermined programmed sequence. Each individual transceiver, when polled, transmits a radio-frequency signal, frequency modulated with a 4,000-hertz sine wave. Although 4,000 hertz is recommended, any frequency compatible with the system bandwidth and DTOA measuring equipment can be used. All transmitted signals are passed through the relay stations to the relayed signal receivers. These signals are demodulated to recover a 4,000-hertz signal through each relay station. The DTOA for each pair of signals is equal to the difference in electrical path length. DTOA for each pair of signals is measured, integrated over a large number of samples, and fed to the processor. Each DTOA measurement represents a hyperboloid that passes through the object. Location of the object is computed from simultaneous measurements of signals through three or more relay stations (two or more pairs). A series of position measurements is used for monitoring object movements. The concept also provides for transmission of data originating at the object.

Although phase 2 has not yet been completed, limited laboratory and field tests tend to confirm the applicability of the system design.

U.R. Barnett, Jr., 867-3017 PT-TPO-A



System block diagram.



Typical location of relay stations and transceivers.

Multispectral Analysis of Nuclear Magnetic Resonance (NMR) Imagery

KSC, Washington University in St. Louis, Missouri, and the University of Florida are working jointly on pioneering research with NMR imagery. NMR is a new medical diagnostic tool that has great potential for solving medical problems that currently have no solution. KSC

and University of Florida engineers are applying NASA multispectral image processing technology for the purpose of analyzing NMR medical data obtained from Washington University's Mallinckrodt Institute of Radiology physicians.

Private industry, including Siemens Company, General Electric, and McDonnell Douglas, are very much interested in this activity and are monitoring the progress for applicability to their commercial NMR systems.

NMR imagery includes sets of data for proton density and relaxation times that are in registration for multiple sections through an organ or body region of interest. An analogy exists between satellite imagery and simultaneous sets of NMR images at the same anatomic level with different contrasts (e.g., proton density, T_1 and T_2).

Satellite images, such as those from the LANDSAT, are available in sets where the elements of each set are individual frames of visible light, near infrared, far infrared, and others. Advanced image processing systems for the analysis of satellite data have been constructed by NASA and others.

Simultaneous sets of NMR data (proton density, T_1 and T_2) have been converted into a format that is compatible with a satellite image processing system (General Electric Image 100) owned by NASA and operated by the University of Florida. The analysis of these NMR data with the image processing system allows summarizing of the contrasts present in each individual NMR section into a single color image that contains the important contrast information from each of the elements. In this manner, the image processing system can form a single image containing the important information from three or more separate images of the same section. For example, at a given slice location in the brain, a single color image (with near-true color) can be constructed by combining the proton density, T_1 and T_2 , images at the same anatomic location. A computer-generated multispectral classi-

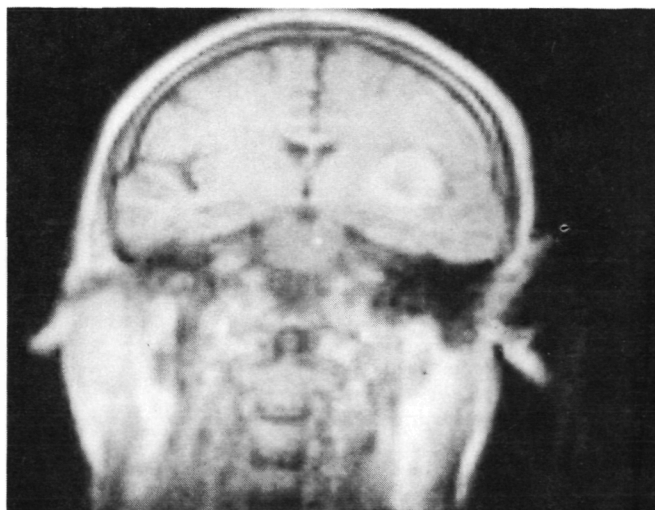
fication of the important features can also be constructed. For example, a green signature area is a hematoma, a light-blue area is white matter, and a dark-blue area is cerebral-spinal fluid.

Activities during the last year were directed at further refinement and application of these techniques. Both the Earth Resources Laboratory, of the National Space Technology Laboratories in Bay St. Louis, Mississippi, and the Jet Propulsion Laboratory in Pasadena, California, became involved with the project to support this. The Mallinckrodt Institute of Radiology at Washington University was enhanced in image-processing capability this year, with KSC consultation; for example, the applications software image analysis program from the Earth Resources Laboratory was delivered to Washington University.

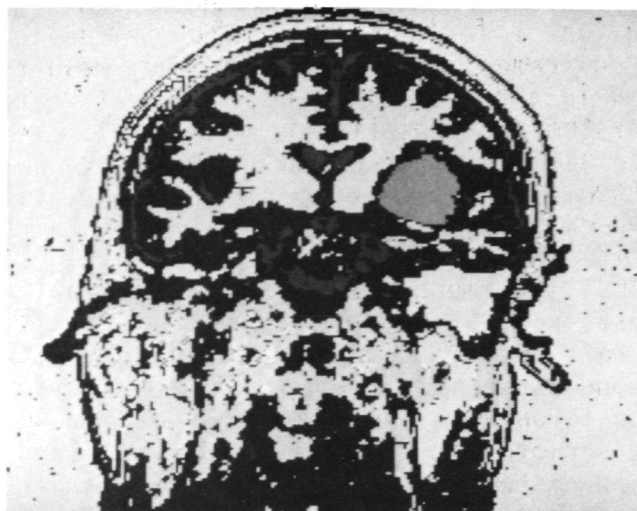
Future activities include optimization of NMR scanner setup parameters, determination of the best image classification schemes for specific diseases, and application of these techniques to larger numbers of cases.

R.L. Butterfield, 867-3017

PT-TPO



Single image containing important information from three or more separate images of the same section of the brain.



Computer-generated multispectral classification of important features of the brain.

Inflight Instrument Flight Rules (IFR) Simulator

The purpose of this study is to examine the commercial feasibility of applying NASA technology to the development of an inflight IFR simulator as a product to support IFR training in a congested traffic area. The product is conceived as an inflight hardware device that presents realistic instrument indications to the pilot, allowing him to interact with the actual aircraft controls while flying. The inflight simulator improves safety of flight conditions and safety of flight during instrument training by allowing the student to practice instrument approaches away from crowded approach facilities. This concept also improves upon ground simulators by replacing the artificial control response of the simulator with the authentic response of the aircraft.

The study was conducted in four phases leading to this final report. Instrument flight training objectives were documented in the first phase, including objectives related to both commercial and military aviation. A survey of fixed base operators and aircraft manufacturers was then conducted to determine the acceptance of the product concept. A system design study was then conducted from the results of the fixed-based-

operators survey and a survey of the avionics field to determine the design requirements. This design study resulted in the definition of three alternate system configurations. Finally, a marketability analysis was conducted to determine the prospects for a financially successful product development.

The recommended system configuration uses radio frequency stimulation of aircraft landing aids in combination with long-range-navigation (LORAN-C) aircraft positioning. This approach allows the instructor to simulate instrument-landing-system approaches to imaginary airfields at any designated location. The approaches can be flown in combination with existing navigation aids (very-high-frequency omnidirectional radio range, tactical air navigation, etc.). Multiple approaches can be conducted in succession without the need to return to a specific position to begin each approach. This method was selected after considering installed system cost, certifiability, and safety of flight.

The marketability survey indicates that the primary market for the device is in domestic military training. Foreign military markets are the second most profitable market. The general aviation market is considered to be least profitable, though the market might be reexamined following a successful marketing of the system to the military. None of the markets is considered to be adequately profitable without some level of Government sponsorship of research and development costs. Because of the potential profitability of the military training market, the development of the prototype demonstration system in a general aviation aircraft is recommended as the second phase of the IFR technology transfer program. A successful military marketing program is believed to be contingent upon demonstration of a sample device. Installing the device in a general aviation airframe would enable a demonstration of the operation of the system under flight conditions and would guarantee the certifiability of the system installation.

L.C. Parker, 867-7390

SF

PROJECT REFERENCE DATA*

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
High-Purity Oxygen Production	K. Buehler 867-3332 DD-MED-43		OSF
Natural Condensation Flow and Heat Transfer of Oxygen in a Helically Coiled Heat Exchanger	F.N. Lin 867-4156 DD-MED		OSF
The Effect of Sense Line Length on Water-hammer Pressure in a Cryogenic Flow	F.N. Lin 867-4156 DD-MED		OSF
Magnetic Refrigeration of Liquid Hydrogen Boiloff	F.S. Howard 867-3202 DD-MED-4	Los Alamos National Laboratories (Dr. J. Barkley)	OSF
Polygeneration	G.P. Gutkowski 867-2196 DF-PEO		OSF
Nitrogen Tetroxide (N ₂ O ₄) Thermophysical Properties Tables	F.S. Howard 867-3202 DD-MED-4	National Bureau of Standards	OSF
Hypergolic Fuel Absorber and Neutralizer	R.A. Gerron 867-4493 SF-ENG	Auburn University (Dr. B. Tatarchuk)	OSF

*AD/CDDF = Deputy Administrator/Center Director's Discretionary Fund
 OAST = Office of Application and Space Technology
 OCE = Office of the Chief Engineer
 OER = Office of External Relations (Technology Utilization)
 OSF = Office of Space Flight

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Fiber-Optic Liquid-Leak Detector Development	M.E. Padgett 867-3367 DL-NED-12A	Opto-Electronics, Incorporated	AD/CDDF
Pattern Recognition Methods for Toxic Vapor Detection Using Microsensors	W.R. Helms 867-4438 DL-NED-32	Naval Research Laboratory	OSF
Hazardous Gas Detection System (HGDS)	W.R. Helms 867-4438 DL-NED-32	Naval Research Laboratory	OSF
Evaluation of a Process Gas Analyzer as a Backup Subsystem for the Primary Hazardous Gas Detection System (HGDS)	W.R. Helms 867-4438 DL-NED-32		OSF
Turbomolecular Pump Testing for Launch Vibration Tolerance	W.R. Helms 867-4438 DL-NED-32		OSF
	C.V. Moyers 867-4614 DF-MAO-2		
Low-Cost, Low-Concentration Hydrogen (H ₂) Leak-Detection Instrumentation Evaluation	W.R. Helms 867-4438 DL-NED-32		OSF
Ambient Influences Upon the Sybron/Taylor Oxygen (O ₂) Depletion Detector	W.R. Helms 867-4438 DL-NED-32		OSF
	S.G. Zurek 867-4449 DL-NED-32		

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Low-Oxygen-Concentration Detection	R.A. Gerron 867-4493 SF-ENG	Niagara Scientific, Incorporated	OSF
Remote Sensing of Hydrazines	P.M. Rogers 867-3842 DL-DED-32 M.M. Scott, Jr. 867-3086 DL-DED-32	Jet Propulsion Laboratory (Dr. W.B. Grant)	OAST
Hydrazine Personal Dosimetry	W.R. Helms 867-4438 DL-NED-32	Naval Research Laboratory	AD/CDDF
Evaluation of Commercially Available Hydrazine Detectors	W.R. Helms 867-4438 DL-NED-32	Naval Research Laboratory	OSF
An Evaluation of Hydrazine Detectors Based Upon Emerging Technology	W.R. Helms 867-4438 DL-NED-32		OSF
Large-Volume Area Fire-Detection Instrumentation	R.W. Hamilton 867-2712 DD-FED-22	Spectra Research Systems	OAST
Mechanically Induced Settling Technology	F.S. Howard 867-3202 DD-MED-4	National Bureau of Standards	OSF
Putting Aerosol Particle Monitors to Work in the Field	W.R. Helms 867-4438 DL-NED-32		OSF

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Flow Metering by Laser/Fiber-Optic and Vortex Shedder Devices	R.M. Howard 867-3366 DL-DED-3	University of Florida (Dr. E. Farber)	OSF
Liquid Level Instrumentation Using Gamma Ray Sources	R.M. Howard 867-3366 DL-DED-3	University of Florida (Dr. E. Farber)	OSF
Artificial Intelligence Research	J.R. Jamieson, Jr. 867-0790 SE-FSD		AD/CDDF
	C.I. Delaune 867-5020 SC-LPS-2		
Operational Intercommunication System - Digital (OIS-D)	D.D. Lovall 867-4548 DL-MED-1		OSF
	F. Byrne 867-4046 SC		
High-Speed Digital Multiplexer/Demultiplexer Development	T.L. Herring 867-3843 DL-DED-32	Martin Marietta Corporation	OSF
Invar Pipe Weldments	R.A. Dyke, Jr. 867-3400 DE-MAO-3		OSF
High-Pressure Oxygen Testing Program	C.J. Bryan 867-4614 DE-MAO-2		OSF

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Testing for Electrostatic Charge on Materials	H.M. Delgado, Jr. 867-3367 DL-DED-31		OSF
	C.L. Springfield 867-4614 DE-MAO-2		
Ablative Material Testing Program	B.J. Lockhart 867-4614 DE-MAO-2		OSF
	C.J. Bryan 867-4614 DE-MAO-2		
Orbiter Thermal Protection System (TPS) Waterproofing	F.E. Jones 867-0728 SE-MSD-11	Battelle Columbus Laboratories	OAST
A Hypobaric Method for Plant Growth in Microgravity	W.M. Knott, III 867-3152 MD-ENV		AD/CDDF
KSC Laboratory Sled Head-Restraint System	W.R. Munsey 867-4670 CP-FSO		OSF
	I.D. Long 867-3165 MD-MED		
Life Science Biological Research Program	W.M. Knot, III 867-3152 MD-ENV		OSF

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Rocket-Triggered Lightning Program (RTLTP)	W. Jafferis 867-0526 SO	Air Force Wright Aeronautical Laboratories	OSF
		Federal Aviation Administration	
		Eastern Space and Missile Center	
		University of Arizona	
		University of Florida	
		State University of New York at Albany	
		Naval Research Laboratory	
		ONERA	
Improved Short-Term Forecasting of Lightning at KSC Based on Surface Wind Convergence	W. Jafferis 867-0526 SO		OSF
Thunderstorm Currents	R.P. Wesenberg 867-4438 DL-NED-31	University of Arizona	OSF
Shuttle Inventory Management System (SIMS)	E.F. Brimberg 867-4857 DL-DED-1	Computer Sciences Corporation	OSF
Configuration Management Data System (CMDS)	L.A. Wilhelm 867-7582 DL-DED-21	Planning Research Corporation EG&G Florida, Incorporated	OSF

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Logistics and Expert Systems	G.A. Opresko 867-7898 PT-LMO	Rand Corporation	OSF
Spares Quantification	G.A. Opresko 867-7898 PT-LMO		OSF
Material Accountability	G.A. Opresko 867-7898 PT-LMO	EG&G Florida, Incorporated EG&G Washington Analytical Services Center, Incorporated	AD/CDDF
Application of Voice-Interactive Maintenance-Aiding Device (VIMAD) Technology	J.B. Lansing 867-4888 SF-SAF-3	Honeywell, Incorporated	OCE/OSF
Application of Surrogate Travel Technology	J.B. Lansing 867-4888 SF-SAF-3	Interactive Television Company	OCE
Tactical Air Navigation (TACAN) Beacon Calibration	H. Perkins 867-4438 DL-NED-31		OSF
Application of NASA Technology for Automatic Location and Tracking of Subjects	U.R. Barnett, Jr. 867-3017 PT-TP0-A	Wood-Ivey Systems Corporation (J. Bowling)	OER
Multispectral Analysis of Nuclear Magnetic Resonance (NMR) Imagery	R.L. Butterfield 867-3017 PT-TP0	Washington University (Dr. M. Vannier) University of Florida	OER

ITEM	RESPONSIBLE INDIVIDUAL	PARTICIPATING ORGANIZATION	NASA HEADQUARTERS SPONSOR
Inflight Instrument Flight Rules (IFR) Simulator	L.C. Parker 867-7390 SF	Pacer Systems, Incorporated	OER

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15. Abstract <p>As the NASA Center responsible for assembly, checkout, servicing, launch, recovery, and operational support of Space Transportation System elements and payloads, Kennedy Space Center is placing increasing emphasis on the Center's research and technology program. In addition to strengthening those areas of engineering and operations technology that contribute to safer, more efficient, and more economical execution of our current mission, we are developing the technological tools needed to execute the Center's mission relative to Space Station and other future programs. In connection with the increasing emphasis on research and technology, the Directorate of Engineering Development encompasses most of the laboratories and other Center resources that are key elements of research and technology program implementation and is responsible for implementation of the majority of the projects in this Kennedy Space Center 1984 Annual Report. The report contains brief descriptions of research and technology projects in major areas of Kennedy Space Center's disciplinary expertise.</p> <p>For further technical information about the projects, contact Albert E. Jorolan, Engineering Development, Research and Technology Manager, DL-RT, (305) 867-4856. James M. Spears, Chief, Technology Projects Office, PT-TPO, (305) 867-7705, is responsible for publication of this report and should be contacted for any desired information regarding the Center-wide research and technology program.</p>					
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